DOE/NASA
Review Committee Report

on the

Technical, Cost, Schedule, and
Management Review

of the

Gamma-Ray Large Area Space Telescope

LARGE AREA TELESCOPE (LAT) PROJECT

May 2003

EXECUTIVE SUMMARY

On May 12-16, 2003, a joint Department of Energy (DOE) and National Aeronautics and Space Agency (NASA) Committee conducted a review of the Large Area Telescope (LAT) project at Stanford Linear Accelerator Center (SLAC). The LAT is being jointly developed by DOE and NASA, and is the principal scientific instrument on the space-based NASA Gamma-ray Large Area Space Telescope (GLAST) Mission, currently scheduled for launch in September 2006. Four foreign partners (France, Italy, Japan and Sweden) are also participating. The LAT Collaboration was organized by DOE- and NASA-supported scientists and with scientific teams from the foreign partners. Professor Peter Michelson, who holds a joint appointment at Stanford University and SLAC, serves as the Instrument Principal Investigator for the LAT project and spokesperson for the Collaboration. A Joint Oversight Group has been formed at the Headquarters level of NASA and DOE to coordinate agency oversight of the project.

The LAT is a gamma-ray telescope, designed to measure the energy and direction of gamma rays incident from space with energies approximately 20 MeV to greater than 300 GeV. The scientific objectives of the LAT include the study of the mechanisms of particle acceleration in astrophysical environments, active galactic nuclei, pulsars, and supernova remnants. They also include the resolution of unidentified galactic sources and diffuse emissions from cosmological sources, as well as determination of the high-energy behavior of gamma-ray pulsars, gamma-ray bursts, and transient sources. Among other topics of cosmological interest, these data will give information on extragalactic background light in the early universe and dark matter. Main components of the instrument include a silicon-strip track detector, a calorimeter, an anti-coincidence detector and a data-acquisition system.

This joint DOE/NASA review follows the one held in July 2002 in which the committee recommended approving the LAT project for baseline status and proceeding to the next phase of development based on the results of the Preliminary Design Review. Quarterly status reviews, held in November 2002 and January 2003, highlighted unresolved technical issues and schedule delays in several subsystems, as well as the corrective action plan put in place to resolve these issues. In the baselined schedule, the project was holding 17 weeks of internal float at the end of their fabrication phase. Over the past few months, the current internal schedule of the project has been slipping and is currently about one month behind its baselined schedule.

At the end of April, the French Space Agency (CNES) announced that funding for GLAST had been removed from its program. CNES funding was to cover procurements, engineering design, and technical labor in the Calorimeter (CAL) subsystem at CNES, as well as the French National Center for Scientific Research (CNRS) institutions. To keep the project on schedule, the CNES-funded procurement of the Crystal Detector Elements for the CAL, which was on the critical path, was moved to a U.S. contractor which already had experience with this hardware. The cost of approximately $5 million is being funded out of contingency until other funding can be arranged. Another critical French responsibility, which is not easily moved to the U.S., is the mechanical structures for the CAL and the project and French institutions are working to ensure that support for this work can continue through CNRS at the IN2P3 laboratory.

The purpose of the current review was to conduct a NASA Critical Design Review (CDR) and the DOE Critical Decision 3 (CD-3, Approve Start of Construction) review in anticipation of proceeding to full scale fabrication activities. At the request of the NASA Goddard Space Flight Center (GSFC) Systems Review Office and the DOE Acting Director of the Division of High Energy Physics, the review was conducted and co-chaired by Mark Goans of the GSFC Systems Review Office and Daniel Lehman, the DOE Director of the Construction Management Support Division. The Committee was charged with doing an integrated examination and assessment of the final design of each subsystem, as well as the entire project, including a technical design, cost, schedule, management, and a risk examination, keeping in mind the issues from past reviews and progress since the approved baseline. The Committee consisted of 16 scientific and engineering experts in the fields of High Energy Physics, Astrophysics, and Spaceflight. DOE and NASA observers were also in attendance.

In terms of its assessment of the technical design, the Committee felt that the project has made good progress since the January 2003 DOE/NASA review. There are still some designs that need to be finalized, documented, and tested over the next few months and recommendations for resolution were made by the Committee. The biggest outstanding issues were that the Mechanical/Thermal subsystem needs to complete and verify the design of the calorimeter to grid structural interface and the thermal interface between cross-LAT plate and electronics boxes and the Tracker subsystem needs to complete the environmental testing of the engineering model. An internal peer review will be held to approve the final design in a few months. The ASICS (Application Specific Integrated Circuits) electronics still needs its final design verified in several subsystems. Overall, the Committee found that the design is at the appropriate level of maturity for CDR and CD-3, status contingent upon resolution of the issues listed in the report.

The total estimated cost at completion of $121.7 million with a current contingency of $14.2 million (23 percent of the costs-at-risk) at 43 percent project completion was felt to be a concern. The project stated that there should be no schedule impact if contingency is immediately used to cover the costs (approximately $5 million) due to the CNES dropout. Additionally, other costs that will affect the contingency were estimated to be $3-5 million. The Committee recommended that the project update the cost estimate, including a contingency analysis, by August 1, 2003. The Committee felt that the costs due to CNES dropping out cannot be covered within the project over the long term and a solution is required by the funding agencies.

The Committee was concerned that the baseline schedule for fabrication of the LAT is in doubt, even if immediate steps are taken to cover the costs due to the CNES dropout. The project has already started to develop and implement work-around plans. The Committee recommended that the LAT management continue to develop additional work-around strategies to the cost and schedule to address risks and add flexibility.

The Committee's assessment of the project management is that it is working well and the tools are mature and effectively used. The Committee felt that the management is dealing appropriately with cost and schedule risks as evident by their rapid response to the CNES dropout and the rescheduling of the beam test. The SLAC Directorate oversight was felt to be significant and of great value to the LAT project.

The Committee reviewed and assessed the status of the international contributions, and noted that the LAT project International Finance Committee had its first meeting in February and the situation with French funding commitments was not foreseen at that time. The Committee commented that the SLAC and LAT management are paying appropriate attention to the situation of the Italian collaborators as well, since there are agency-laboratory and agency-agency letters of agreement that are not signed.

The overall project was reviewed by the Committee in terms of technical design, cost, schedule, risk and management structure, in anticipation of the start of full scale fabrication. The Committee found that the schedule is aggressive and the contingency is light. There are several technical issues that still need to be resolved. The Committee has asked the project, working with SLAC management, to update the cost and contingency analysis as well as reexamine the project for strategies that could mitigate the risks.

In summary, the Committee recommended that DOE approve the project for CD-3 status and NASA approve the project to proceed with implementation based on the results of the CDR, contingent upon resolution of the cost, schedule, and funding issues (DOE) and the technical design issues (NASA).

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1. INTRODUCTION

On May 12-16, 2003, a joint review by the Department of Energy (DOE) and the National Aeronautics and Space Administration (NASA) was conducted of the Large Area Telescope (LAT) project at Stanford Linear Accelerator Center (SLAC). The LAT is being jointly developed by DOE and NASA, along with foreign partners, and is the principal scientific instrument on the space-based NASA Gamma-ray Large Area Space Telescope (GLAST) Mission, currently scheduled for launch in September 2006. Relationships between DOE and NASA for the GLAST Mission and the LAT project are formalized in an Implementing Arrangement (signed by both agencies in January 2002). A Joint Oversight Group (JOG) has been formed at the Headquarters level of NASA and DOE to coordinate agency oversight of the project.

The LAT Collaboration was organized by DOE- and NASA-supported U.S. scientists along with scientific teams from France, Italy, Japan, and Sweden. Professor Peter Michelson, who holds a joint appointment at Stanford University and SLAC, serves as the Instrument Principal Investigator and Spokesman for the Collaboration.

The scientific objectives of the LAT are largely motivated by discoveries using measurements of celestial gamma rays by the Energetic Gamma Ray Experiment Telescope (EGRET) experiment, which was flown aboard the Compton Gamma Ray Observatory, and, for energies above 300 GeV, by ground-based atmospheric Cherenkov telescopes. These objectives include the study of the mechanisms of particle acceleration in astrophysical environments, active galactic nuclei, pulsars and supernova remnants. They also include the resolution of unidentified galactic sources and diffuse emissions from cosmological sources, as well as determination of the high-energy behavior of gamma-ray pulsars, gamma-ray bursts, and transients. Among other topics of cosmological interest, these data will give information on extragalactic background light in the early universe and dark matter.

The LAT Program has been presented to the High Energy Physics Advisory Panel and endorsed by the Scientific Assessment Group for Experiments in Non-Accelerator Physics, both of which report to the Division of High Energy Physics (DHEP). The GLAST Mission is the top-ranked mid-size space-based mission on the recent (2001) National Academy of Science's Decadal Survey on Astronomy and Astrophysics and is part of the NASA Structure and Evolution of the Universe (SEU) roadmap. The LAT proposal was submitted to and accepted by NASA in February 2000 in response to the Announcement of Opportunity (AO 99-OSS-03).

The LAT is a gamma-ray telescope, which will measure the energy and direction of gamma rays incident from space with energies approximately 20 MeV to greater than 300 GeV. The main components of the instrument include a silicon-strip track detector, a calorimeter, an anti-coincidence detector, and a data-acquisition system. The design for the tracker consists of a four-by-four array of tower modules, each with interleaved planes of silicon-strip detectors and tungsten converter sheets. Silicon-strip detectors are able to more precisely track the electron or positron produced from the initial gamma ray than other types of detectors. This is followed by a calorimeter, which has Thallium-doped Cesium Iodide (CsI) bars with photodiode readout, arranged in a segmented manner, to give both longitudinal and transverse information about particle energy deposition. An Anti-Coincidence Detector provides background rejection of the large flux of charged cosmic rays. It consists of segmented plastic scintillator tiles, with wavelength shifting fiber/photomultiplier tube readout. The detector draws on the strengths of the high-energy physics community, typically supported by DOE, for the silicon and calorimeter technology and related physics analysis. Space qualification and telemetry are new dimensions for high energy physics, but well understood in astro-particle physics, typically supported by NASA, as well as the foreign collaborators.

Critical Decision (CD) 0, Approve Mission Need, was given DOE on June 25, 2001. Approval for Preliminary Baseline Range (CD-1) was given August 28, 2002 and approval for Performance Baseline Range (CD-2) was given November 8, 2002. As part of the GLAST Mission, for NASA the LAT project is currently nearing the end of its final design stage (Phase C).

The review was announced by the co-chairs of the JOG: Paul Hertz, the Theme Scientist for the SEU Theme in the Astronomy and Physics Division at NASA, and John O'Fallon, Office of High Energy and Nuclear at DOE. The Chief of the Goddard Space Flight Center Systems Review Office, Josef A. Wonsever, requested that Mark Goans of the Systems Review Office conduct and co-chair the review for NASA. The Acting Director of DHEP, Robin Staffin, requested that Daniel Lehman, Director of the DOE Construction Management Support Division, conduct and co-chair the review for DOE. This review is the fifth in a series of joint DOE/NASA reviews of the LAT project (with previous ones held in August 2001, January 2002, July 2002, and January 2003). These joint reviews fulfill the otherwise-separate requirements of the DOE and NASA management oversight processes.

The January 2003 review focused on preparation for the current review. It followed the joint DOE/NASA baseline and "delta" Preliminary Design Review (PDR) review, held July 2002, in which the committee recommended baselining the LAT project. The technical progress overall was found to be good. There were several issues that were still dynamic and causing the most concern to the project, including: 1) tracker bottom tray design, 2) mechanical connection from grid to calorimeter, and 3) completion of the ASIC electronics designs.

The cost and schedule was seen to be tight and the Committee felt that the foreign partners posed some unresolved risks to the project. The LAT management team was found to be strong and well structured. Overall, the project was seen as strong, but there were still some risks and unresolved issues in its preparation for the upcoming review. The committee felt that the corrective actions put in place by there project were adequate to resolve the technical issues.

The purpose of the current review was to conduct a NASA Critical Design Review (CDR) and a DOE CD-3, Approve Start of Construction, review. For DOE, the review focuses on an integrated examination and assessment of the final design of the entire project in anticipation of the start of fabrication. The successful outcome of the review, at the end of the final design phase, is a prerequisite for DOE CD-3. For NASA, the CDR focuses on the technical design of each subsystem and the integrated instrument in addition to being concerned with its cost, schedule and management structure. The successful completion of a CDR becomes the basis for the start of construction for the project. Achieving this important milestone will pave the way for the GLAST Mission PDR and Non-Advocate Review (NAR) scheduled for June, 2003, and the Confirmation Review, scheduled for August 2003.

Particular charges to the Committee were to do a determination of the status of the technical design, cost, schedule, and management structure of each subsystem, as well as the integrated project, keeping in mind the issues from past reviews and progress since the approved baseline. In addition, the Committee was charged with evaluating the status and time schedule of international contributions. The Committee was asked to comment on whether the maturity of the design and development effort is appropriate and if it justifies supporting the project to proceed with full-scale fabrication activities.

The Committee included scientific and engineering experts in the fields of High Energy Physics, Astrophysics, and Spaceflight. These Committee members had specific areas of expertise applicable to the LAT project. Observers were in attendance from both the DOE and NASA agencies. The NASA Headquarters Independent Review Team also attended the review as observers.

The Committee reviewed the detailed presentations (plenary and breakouts) made by the collaboration members on the scientific and technical aspects of the experiment. In addition, they reviewed the LAT team's responses to requests made by the previous review Committee. Recommendations by the Committee were provided to the LAT team and agency observers during the closeout of the review. Their evaluations in terms of findings, comments and recommendations are contained in this report.

The main body of the report consists of evaluations of each technical system, which are organized according to major subsystems in the work breakdown structure (WBS). The final sections cover cost, schedule, funding and management of the entire LAT project. Appendices include the charge to the committee (A), review participants (B), review agenda (C), cost tables (D), and schedule charts (E). Recommendations resulting from this review are included at the end of each of the sections.

Requests for Actions (RFA) were written during the CDR by the Committee members or others in attendance and forwarded to Mark Goans for coordination. The RFAs (Appendix F) were generated for specific items that are felt to need more explanation than was available at the time.

2. TECHNICAL SYSTEMS EVALUATIONS

2.1 Tracker (WBS 4.1.4)

2.1.1 Findings

As noted in past reviews, this is a well-planned design that can be completed within the required time. The design uses mature and well-tested technologies, so the technical risk is low. The subsystem is managing risks effectively. However, this is a complex system, so thorough testing and verification at all stages of the project are essential.

The subsystem has made good technical progress. Production front-end ASICs (Application Specific Integrated Circuits) are in hand and about 50 percent of the silicon-strip sensors have been delivered and tested with excellent yields. The Italian and Japanese groups are fully integrated and the workflow is proceeding smoothly.

The front-end electronics have been tested at the ladder level and meet specifications. System tests at the tray and tower level are in preparation.

The mechanical design of the bottom tray has been strengthened to address failures noted at the January 2003 DOE/NASA review. Fastenings have also been improved. The adequacy of the new design must be verified by measurements on the Engineering Model Tower.

Key assembly and test procedures are in place. Of 87 drawings, 73 are released and the remaining 14 are in progress.

At the time of the January review, a bottoms-up cost estimate yielded a total subsystem cost of $9.9 million with 25 percent contingency. Meanwhile, Change Control Board actions have increased the total cost to $10.9 million. The cost, to date, is $6.7 million with a remaining contingency of 20 percent. Since pre-production system tests have not been completed, the contingency is low.

The subsystem has coped effectively with delays in the design of the front-end ASICs, but at the expense of schedule contingency. The production schedule remains very aggressive. Subject to verification of the bottom tray and thermal design, the Tracker is at CDR, Critical Decision (CD) 3, Approve Start of Construction, level.

2.1.2 Comments

As noted in past reviews, this is a well planned design that can be completed within the required time. In electronics, results from numerous tests ranging from the component level to a full-balloon flight system support the validity of the adopted architecture. Extensive mechanical tests and analyses have also been performed. System tests at the tray and tower level must be completed expeditiously to verify system performance. The “mini tower” with three x-y trays should be equipped with flight ASICs mounted on production-design Multi-Chip Modules (MCM) and tested thoroughly. Completion of the tower Engineering Model is scheduled for late July 2003. This unit is essential for mechanical and thermal tests to verify the production design and assembly techniques.

Flight ASICs were released for fabrication after an expedited preproduction process. Automated test systems are now in place that will allow full wafer-probe tests of the analog and digital readout ASICs (GTFE and GTRC), so that MCMs can be populated with fully tested integrated circuits. Since schedule contingency is marginal, it is important to keep detailed records of component test results to facilitate diagnoses should unforeseen performance problems arise during production.

Substantial improvements have been made in the mechanical design. The bottom tray has been reinforced and the fastener configuration has been improved. The material used for the carbon fiber Side Panels has been changed to improve cooling of the upper trays. Simulations and component-level tests indicate that the previously observed problems have been resolved, but measurements on the Engineering Model are needed to verify the design.

The Tracker Trays and Towers will be fabricated, assembled, and tested in Italy. Parallel assembly facilities using the same tooling for ladders have been set up at two industrial vendors. Tray assembly is more demanding and is being performed by one of the two ladder assembly sites. The sensors delivered from Japan are of very high quality and the assembly techniques developed by the Italian groups maintain these high standards.

Zero float exists in the tracker schedule for the first two towers. The float jumps to 2.5 months for towers 3-12. The float begins to dissipate for the final four towers due to the vacation schedule in Italy.

At the January 2003 DOE/NASA review two key electronic components were not flight qualified: Polyswitches (now approved) and high voltage chip capacitors. The approval process for the high-voltage chip capacitors is still underway.

A spares plan, as requested at the January review, has been developed and is being revised as production techniques are being tested and refined.

2.1.3 Recommendations

1. Verify the modified bottom tray and thermal design in the tower Engineering Model by the end of August 2003.

2. Test electronics thoroughly in the Mini-Tower by the end of July 2003.

3. Track front-end ASICs from wafer-probe to completed Multi-Chip Modules.

2.2 Calorimeter (WBS 4.1.5)

2.2.1 Findings

The current project configuration, with full French participation, is already behind schedule due to delays in placing the Crystal Detector Element (CDE) contract with French industry.

Loss of funding from CNES places the CDE assembly at considerable risk. A backup plan exists to move production to a vendor in the U.S. with experience in assembling the prototype CDEs. IN2P3, which supplies the calorimeter mechanical structure, is also at risk. Loss of funding from CNES also places this project at risk. A backup plan exists.

The current plan does not call for the electronics module to be outfitted with flight electronics before it is turned over to the Integration and Testing (I&T) team because of schedule concerns. The flight ASICs appear to be in hand for the Calorimeter, based on tests of five chips each. The elastomer used in the PIN diode has no flight history, though it has recently been space qualified.

At the time of the January 2003 DOE/NASA review, a bottoms-up cost estimate yielded a total subsystem cost of $17.8 million with a contingency of 25 percent. The cost to date is $7.6 million.

Withdrawal of CNES funding will increase the required U.S. funding. Pending resolution of the unanticipated funding challenge the calorimeter, at CDR, CD-3, Approve Start of Construction, level.

2.2.2 Comments

The current project configuration, with full French participation, is already behind schedule due to delays in placing the CDE contract with French industry. The contract award was expected on May 23, 2003, with the first 120 CDEs delivered in September. This represents a delay of 27 days relative to the baseline schedule, though the time between contract placement and first deliveries has been squeezed.

Loss of funding from CNES places the CDE assembly at considerable risk. A backup plan exists to move production to a vendor in the U.S. with experience in assembling the prototype CDEs. The delay relative to the current schedule could be small and is not likely to exceed two months. This represents a significant escalation to the U.S. project cost.

IN2P3 is to supply the calorimeter mechanical structure. Loss of funding from CNES also places this project at risk. A backup plan exists for the U.S. to assume responsibility for fabrication of various machined parts, at a cost of $300-$400 K, and for IN2P3 to continue with the carbon fiber structure and to provide titanium inserts and polymeric parts. The cost of the work performed at IN2P3 in this plan is small enough that it could be covered from existing operating funds.

The flight ASICS appear to be in hand for the Calorimeter, based on tests of five chips each. The analog ASIC does not meet the integral linearity specification, but this can be calibrated. The analog ASIC also requires addition of an external resistor for proper bias. This can be accommodated without a board modification.

The calorimeter schedule is unrealistically tight with no margin for error and no time to address the inevitable problems that will result during production. This was true even before recent announcements from CNES. There is concern that the tight schedule might force decisions that under other circumstances would be considered unwise.

Almost all of the flight modules will be in production before the first module is completed. This is a risk that is well known and thought to be mitigated somewhat through careful analysis of the engineering module prior to the beginning of production. However, in order to preserve schedule it is not planned to outfit the engineering module with flight electronics. The Committee believes it is important to provide time in the schedule to incorporate flight electronics into the engineering module to avoid potential problems down the line that could cause far greater schedule delays.

The project management team has responded quickly to the loss of funding from CNES. They are able to quickly implement a backup solution to the CDE assembly because of sound judgment shown many months ago in foreseeing a possible problem and having a contingency plan in place.

Initial testing of five digital and five analog ASICs indicates that they are candidates for the final flight chips, but more chips need to be tested. The chips have some unanticipated features, but work-arounds exist that should preserve overall performance. Integrated circuits must be screened very effectively to avoid rework in the multi-chip modules. If not performed efficiently, this test could become a schedule bottleneck. Screening for functionality is required, rather than full parametric test, so efficient testing should be feasible.

Crystal deliveries are expected to ramp up to 100 for the month of May 2003, and 230 to 250 per month thereafter. Thus far, deliveries have not exceeded 50 per month. It is believed that all boules necessary for the project have been grown.

The PIN diode encapsulation problems identified at previous reviews have been resolved. The selected material is flight qualified but has no flight history. Accelerated life testing of the PIN diode elastomer should be performed. Setting aside a few devices for long term monitoring would also be wise.

2.2.3 Recommendations

1. Move quickly to implement backup plans to offset loss of funding from CNES.

2. Develop and implement a workable schedule with realistic float that incorporates the backup plans as soon as the details of the backup plans are understood.

3. Outfit the engineering module with flight electronics before turning it over to Integration and Testing. Sufficient time should be allocated in the schedule to make this possible.

4. Perform accelerated life testing of the PIN diode elastomer by the end of 2003, since this material has not flight heritage.
5. Develop an efficient test program to verify the functionality of the ASICs before installation on the readout board, by the end of August 2003.

2.3 Anti-Coincidence Detector (WBS 4.1.6)

2.3.1 Findings

As noted in past reviews, this is a straightforward design using conservative technologies with low technical risk. Tiles and wavelength shifters are assembled by an experienced Fermilab group.

Front-end ASIC design was initiated at GSFC, but moved to SLAC to produce a usable design. The current chip set is usable for electrical performance tests, but does not meet specifications. The outstanding problems have been analyzed and revised designs are in preparation. The micrometeoroid shield was redesigned to meet updated requirements. Fiber routing and mechanical design have been improved.

At the January 2003 DOE/NASA review, a bottoms-up cost estimate yielded a total subsystem cost of $10.3 million with 25 percent contingency. The total cost remains unchanged. The cost to date is $6.1 million with a remaining 30 percent contingency. The Anti-Coincidence Detector (ACD) is fully funded by DOE/NASA. Given the modest scope of this subsystem, both the cost and schedule appear comfortable. The ACD system is at CDR, CD-3, Approve Start of Construction, level.

2.3.2 Comments

The ACD utilizes proven technologies in a straightforward manner. There are 194 plastic scintillator tiles that are read out via optical fibers to a bank of photomultiplier tubes (PMTs). With a total power dissipation of 10 W it requires a low-power design. Limited space requires clever and careful design of the photomultiplier bases and light-tight packaging. Good solutions have been developed.

The biggest problem is the lack of ASICs that meet flight specifications. Several design cycles at GSFC did not provide usable Integrated Circuits (IC) and the effort was moved to SLAC. This placed an additional burden on an already oversubscribed group and led to incomplete simulations. The last submissions fixed some, but not all problems, both on the analog and digital ICs. The available ICs do allow electronic tests, so that board and system level tests can proceed.

A mitigation plan exists that offers good prospects of receiving flight qualified chips in the next fabrication run.

ICs must be screened very effectively to avoid rework in the multi-chip modules. If not performed efficiently, this test could become a schedule bottleneck. Screening for functionality is required, rather than full parametric test, so efficient testing should be feasible.

2.3.3 Recommendations

1. Thoroughly simulate and review revised ASIC designs before submission for fabrication.

2. Develop an efficient test program to verify the functionality of the ASICs before installation on the readout boards, by the end of August 2003.

2.4 Electronics, Data Acquisition, Flight Software and Electrical Systems (WBS 4.1.7)

2.4.1 Findings

The GLAST electronics and flight software subsystem cost and schedule were baselined at the January 2001 DOE/NASA review. The scope of the subsystem has not changed, the cost has increased from $15.7 million to $16.7 million, and there is 27 percent contingency. Since the PDR, impressive progress has been made in a large number of areas.

The LAT electronics and data acquisition system consists of 16 tower electronics modules (TEM), 16 tower power supply modules, two power distribution units (PDU), two global trigger, event builder, ACD electronics modules (GASU), three event processing units (EPU), and two spacecraft interface units (SIU). The EPU and SIU boxes contain the identical set of boards, a storage interface board (SIB), a LAT communication board (LCB), a power supply board (PSB), and a RAD750 CPU. All boxes and boards exist either as development units, engineering models, or models ready to be fabricated as flight models. Mixes of these elements are in use in test stands for the tracker, calorimeter, ACD, and flight software development.

There are three ASICs distributed across these systems, the GCCC (calorimeter cable interface) and the GTCC (tracker cable interface) on the TEM modules and the GLTC (global trigger) on the GASU. At the time of the Delta PDR, these ASICs were implemented in commercial FPGAs coded in VHDL. The process of targeting this code into ASICs was accomplished since the Delta PDR. At the present level of testing, all three ASICs are functioning and could be advanced to flight parts by screening and qualification.

The Committee noted that a CPU selection has been made since the Delta PDR, the BAE RAD750. An approved parts list for the electronics is well advanced and a test plan has been agreed to for the qualification and testing the remaining COTS parts and ASICs. FPGA designs have been submitted to GSFC for design practices review.

The plans for a hardware test bed were presented. This powerful tool will contain a complete set of data acquisition electronics. Sixteen flight design TEM boards will be connected to one real tower and 15 tower front end simulator board pairs. Identical simulator boards will provide ACD data. The simulator boards can be downloaded with Monte Carlo generated data to verify the fidelity of the event filters and cross check the Monte Carlo model of the front end data format.

A spacecraft-LAT ICD now exists. The specification for access to the SSR on the spacecraft side has resulted in a change of the way the LAT accesses this unit. This is now implemented on the GASU board; the EPUs and SIUs transfer data to the SSR through this board. The interface to the spacecraft power system is now defined and a LAT grounding and shielding plan is in place. A quick summary of the state of the circuit boards is:

- TEM—The flight design PCB order will be submitted by May 23, 2003. Sufficient quantities for the test bench and other test stands will be produced. Sufficient ASICs are available to populate these boards.
- TEM power supply—This has been issued as a bid package, responses are being reviewed.
- GASU—The flight design PCB is in fabrication.
- PDU—The PCB will be submitted by May 23, 2003.
- SIB—A flight design PCB is in layout at an outside contractor.
- LCB—The flight design PCI version of the previous PMC implementation is in layout.
- PSB—A flight design layout is underway.
- PCI backplane—A commercial vendor is modifying an existing design to LAT specifications.

Much progress has been accomplished if the flight software area since the Delta PDR in July 2002. The Committee continued to have great confidence in the technical and management skills of the software developers. Critical software developers have extensive experience in the field of high-energy physics and the team has been supplemented by quality engineering services from the Naval Research Laboratory. Nevertheless, the software team is still facing a code development rate much higher than industry standards, possibly as high as 30 lines of code per day.

The flight software team generated a software requirements document in spring 2002. While it has been baselined by the LAT project management it has also been criticized for containing insufficient detail, most notably by NASA engineers, during a Requirements Peer Review in December 2002. Further, it appears that NASA project management is not a signatory on the requirements document. The software team also conducted a peer review in March 2003. A few actions from this review remain open and are being iterated for closure.

The team plans to iteratively design and construct software over the course of three build developments. The full scope of details for the software design has not been identified at this time, although a high level architecture and top-level design has been shown for the three builds. The team has a good understanding of the functionality required for the software builds and for the hardware configurations that each build is required to support.

The flight software team is using a different test and verification system than the systems being used by instrument I&T, the spacecraft vendor and the Mission Operations Center. Talks have begun on how the command and telemetry database can be shared among all these systems.

The software team has a solid understanding of their fault detection and corrective action responsibilities. The instrument hardware is isolated from software errors and no hazardous conditions arise from software failures. Non-hazardous but serious failures fall into two categories: communication failures and memory failures. The software plan is either to telemeter the condition to the ground and await intervention, or to reboot the system.

2.4.2 Comments

Most elements of the DAQ hardware are at or beyond the CDR level. With the exception of the PDU and TEM Power Supplies, engineering models of each electronics circuit card exist and have undergone extensive testing. In addition, the circuit cards comprising the DAQ electronics have been interconnected and tested as a system. All system requirements are being met at this time. The lack of an engineering model for the PDU, at this point in the schedule, is not seen as a great risk since the PDU card is a fairly straight foreword design consisting of LAT standard communication FPGA and several MOSFETS to switch power to LAT system electronics boxes.

The Tower Power Supply development has been flagged by the DAQ electronics lead as a moderate risk. This is a procured item. A request for proposals (RFP) has been issued, and responses have been received and are being evaluated. An alternate plan for the development of this unit has been completed in case the cost and or schedule proposed in responses to the RFP are unacceptable.

The LAT electrical system harness interconnects the electronics boxes on the LAT baseplate. This harness consists of a large number of cables connecting 39 boxes. Spacing between boxes is fairly tight in some areas. Currently a baseplate harness mockup is not planned. Wiring to a harness mockup would provide the best fit harness with the least amount of stress at the connectors. One should be considered.

Complete EMI/EMC testing is planned for the qualification units. However, no EMI/EMC testing is currently planned for the flight units at the box level. Limited conducted EMI/EMC testing of the flight boxes would help to uncover any hidden problems prior to delivery to integration and would reduce the risk of schedule slip during I&T caused by box problems.

The LAT electronics has a requirement to control the VCHP in the thermal control system. Testing of the control system with the heat pipes at Locheed Martin will be required. At this point, it appears that the planning and definition of the test and the required SLAC support for this test has not been addressed.

Staffing and schedule remain as risks to the successful production of the software system. It is unrealistic to expect a production rate two to three times greater than the industry average. In addition, problems with hardware and software tools will surely arise impacting the software development schedule. To address these impacts and to mitigate schedule risk, additional support should be added to this critical area.

Technical margins appear to be adequately planned to handle any unplanned increase in software size, event data rates, and to support operations and sustaining engineering. The software actions for communications and memory faults seem appropriate and correctly protect the hardware.

The use of LTX for the flight software test and verification program creates additional complexity for the software, integration and testing, and operations efforts. The details of how the flight software command and telemetry database will translate into the I&T database are not yet clear, nor has this process been demonstrated. Further, there seems to be no capability for leveraging LTX test procedures in the I&T EGSE environment. Surely, the flight software team will be producing valuable work that should be retained. Duplicating software tests at the I&T level will be unwise. A recommendation pertaining to this subject is in the I&T Section of this report.

2.4.3 Recommendations

1. Develop a verification plan, including schedule, for the VCHP control design by June 20, 2003. Also identify the required LAT hardware and flight software needed to support testing at Lockheed Martin.

2. Provide a LAT baseplate mockup to the harness manufacturer to aid in harness fabrication.

3. Include a conducted emissions and conducted susceptibility test in the box acceptance testing.

4. At the software PEER review currently scheduled for mid-August 2003 prepare a software design documentation package presenting the software design for EM2 in the form of inputs, outputs, and processing (algorithms) for each of the packages. Intercommunication between packages should be identified. The software design traces to software requirements should be shown

5. Investigate options, by mid-June 2003, for the addition of engineering resources tasked with the responsibility of developing test procedures, maintaining the Software Test Plan, and defining a test procedure development schedule.

6. Complete any trade-offs for selecting a command and telemetry database meta-language and implement the database in the flight software test environment.

2.5 Mechanical Systems (WBS 4.1.8)

2.5.1 Findings

Significant technical progress has been made since the July 2002 Delta PDR. Mechanical designs across LAT have matured, interface documentation has been much better defined, and integration and test plans have been significantly enhanced. However, there are several significant items that must be verified before the mechanical and thermal subsystems can be determined to be at the CDR level. These items, noted below, are listed as liens to a fully successful LAT Instrument CDR.

1. **Calorimeter to Grid Structural Interface.** There has been a long-standing concern with the ability of the Calorimeter to Grid friction joint interface to withstand qualification loads, particularly near the spacecraft to LAT mounting locations. Because of load peaking at these locations, friction alone was determined to be insufficient to carry the interface loads and prevent joint slippage. The addition of shear pins at this interface is deemed a positive step. Also, the grid lower flange was redesigned to incorporate the spacecraft interface bracket (previously bolted and pinned to the grid) and to spread the load from the spacecraft flexures more along the length of the grid. Early analyses indicated a fundamental frequency drop of the LAT instrument (below the 50 Hz requirement) and larger deflections of the tracker towers as a result of pinning the interface. It is anticipated that additional analyses and tests will show these preliminary results to be primarily an artifact of the initial, conservative analyses. A final design solution that satisfies the structural requirements of this critical interface must be achieved before LAT can be determined to be at CDR level. It should be noted that the mechanical team is currently working diligently on a design that has shown promise.

2. **Thermal Design of the Tracker Tower and the X-LAT Plate to Electronics Boxes Interface**. The fundamental thermal control architecture established at the Delta PDR remains viable, however, it has been pushed to its limits with respect to its heat rejection capability. In addition, two elements of this architecture continue to require development. These areas of development represent two liens on the CDR presented thermal system architecture. These liens involve the verification, through engineering model programs, of the thermal design approaches baselined for the Tracker and the X-LAT/Electronics thermal joint. The successful completion (i.e., verification test results support modeling/design/analysis assumptions) of these programs will constitute the successful completion of the project CDR with respect to its Thermal Control Subsystem.

   The temperature control of the Tracker is dependent upon the conduction paths provided by the high conductivity composite shear panels that tie each tray into a vertical array through many bolted connections. The path from the Tracker Assembly to the Grid structure is through multiple sets of copper straps that are integrated to the bottom tray.

The effectiveness of these conduction paths directly affects the ability to do successful science by maintaining Tracker temperatures less than 30° C. The engineering program thermal goal is to validate this design approach.

With respect to the LAT electronics boxes, their temperature control is dependent upon the quality of the flexible thermal joint between the X-LAT heatpipe panel and each electronics box. The proposed use of a low pressure thermal joint (1 to 3 psi) that utilizes a new material with no actual flight heritage (Vel-Therm gasket material) as the only (no other mechanical paths such as bolts or straps) heat transfer path for the 370W electronic heatload is a risk at the highest level. The engineering program goal is to comprehensively validate this design approach.

3. **Tracker Engineering Model (EM) Completion of Environmental Testing**. Because of previous test failures of the lower tray in the tracker towers, a successful test of the EM Tracker Tower is deemed necessary to completely eliminate concerns surrounding this issue. Although substantial detailed analyses have been conducted that shows positive margins for the current design, numerous changes have been made to the lower tray and sidewalls and must be verified. Design modifications to the bottom tray include material changes, adding titanium corner fittings, and increasing the diameter of several of the mounting fasteners. The composite sidewalls now have metallic inserts at the lower tray attach points and the sidewall material may change to provide better thermal conductivity. However, this new material (K13D) may have reduced structural properties. Tests of this material are currently in progress and, if selected for flight, must be a part of the EM testing.

A high fidelity LAT structural finite element model (FEM) with over 60,000 nodes was also presented. The major change here is that the FEM model has now been moved to NASTRAN (previously ANSYS) to be compatible with Spectrum Astro spacecraft and the launch vehicle models. New and improved models for many of the subsystems have been incorporated and a series of check runs were conducted to validate the model. The model was also updated to improve dynamic analysis capabilities.

Mass margin is considered adequate at CDR, especially considering that almost 50 percent is measured, and the majority of this is the hundreds of CsI logs in the Calorimeter. Of the remaining 50 percent of mass, 36 percent is calculated, and just 14 percent is estimated. The estimated mass of LAT is 2679 kg compared to the mass requirement of 3000 kg. Therefore, there is 321kg of mass reserve, which is close to 20 percent of the non-measured mass.

The thermal design has experienced temperature creep from PDR resulting from a radiator configuration change deceasing its efficiency, an increase in instrument dissipation (from 602W to 615W) and a thermal blanket outer layer change (from FOSR to Germanium Black Kapton). These changes along with an enhanced VCHP model that more accurately modeled this device, as well as a better-defined Sky Survey analysis case, have taken the design to near its operating limit as defined by the Tracker Hot Spot Temperature of 30° C. The LAT project needs take actions to regain some thermal design margin for the hot design case.

With respect to the actively controlled aspects of the thermal control system, the heater control circuit architecture has adequate redundancy. There are redundant survival circuits with quad redundant thermostats in each heater circuit. VCHP reservoir operational heater circuits are redundant and are controlled with electronic thermostats. However, over-temperature protection needs to be added to the VCHP reservoirs that would prevent a catastrophic failure of the radiator panel due to the inadvertent enabling of both primary and redundant sets of reservoir heaters during survival mode.

Mechanical ICDs that encompass thermal requirements have been completed and are signed. However, several thermal interface requirements to the LAT Grid are awaiting the results of the engineering model test programs and are considered liens on the CDR design.

The overall thermal systems analysis is well done and is at CDR level quality. The design cases are well thought out and bound the system operation. The Thermal Math Model (TMM) maturity is excellent and has fully integrated instrument models. The analysis has characterized failure scenarios, as well as examined temperature sensitivities to conduction, radiation, and power parameters. However, the analysis shows little design margin (.6° C) against the operating limit (defined as Hot Spot) of the Tracker and a negative margin for the failed heatpipe scenarios. However, it is not clear what requirement is being levied on the design with respect to a failed heatpipe condition, i.e., maintain operating limit or acceptance limits. This system requirement needs to be clarified.

The adequacy of the thermal design of each electronics box could not be assessed due to the lack of presentation material in this area. However, it was noted that a comprehensive thermal analysis was completed that addressed all powered components with calculated part junction temperatures with no exceedances. It has also been noted that the lead Thermal Systems engineer is not responsible for the box level thermal designs and analyses. This responsibility lies with the electronics group. The project needs to ensure that the thermal/mechanical packaging analyses and designs are sufficiently reviewed.

The LAT Thermal System verification includes thermal balance testing at the appropriate configuration levels. Thermal Vac temperature test levels (workmanship screening) must be evaluated for consistency with GEVS and the project MAR. MGSE identified for the LAT Thermal Balance test is well planned and comprehensive. The instrumentation for the LAT Thermal Balance testing must provide the accuracy of power measurements that is required for TMM correlation. The project instrumentation plan needs to be implemented. In addition, the process for making the "wet joint" at the radiator-heatpipe-grid interface requires further development and has been identified as such. The core components of the thermal architecture (radiator assembly, Grid CCHPs, and Xlat Heatpipe Panel) have sufficient verification at the vendor location prior to delivery to LAT.

Significant new hires have been added to the mechanical systems team, although many of these hires were brought in fairly recently and much later than originally planned. There are still some additional hires (stress analysts and technicians) needed to fully staff the team and attempt to make up for some of the schedule time lost. A re-plan of work must be accomplished to determine the full extent of the schedule impact of not adhering to the baseline hiring plan. Data showed that they are approximately four man-years behind plan. Clearly, design finalization has been impacted and an evaluation of a critical milestone element, the Grid structure, was conducted.

The Grid is the primary structural support element for LAT and it appears to be four months behind the current milestone schedule, which shows the fabrication contract awarded on May 30, 2003. An RFP for the Grid structure has not been released due to the unresolved calorimeter to grid interface design issue, which is scheduled for resolution in mid-July 2003. In addition, the procurement turnaround time is typically two months. Some schedule relief might be gained if a "planning PR" can proceed without final details of the grid to calorimeter interface being completely defined.

There are significant cost concerns for the mechanical systems. The baseline plan shows a $10.4 million cost with $2.6 million contingency ($4.1 million has been costed to date). Therefore, the system would appear to have adequate contingency (42 percent) on the remaining cost of $6.3 million. However, an estimate of $1.6 million was provided for scope changes and delays in awarding the second phase of the thermal support contract with Lockheed Martin. Other cost impacts include qualifying the X-LAT to electronic thermal interface ($250 K preliminary estimate) and for performing a more comprehensive strength test of the Grid structure ($100 K preliminary estimate). If these costs are accurate and were funded completely out of contingency, then the remaining contingency is only $600 K and would be less than ten percent of cost to complete.

2.5.2 Comments

Many Requests for Action (RFA) are still open from the PDR, Delta PDR, and recently completed pre-CDR Peer Reviews. Progress should continue toward their timely completion.

There is concern regarding fabrication of the Calorimeter composite housings if the current French vendor is not selected/funded. This complex and precise assembly requires detailed processes and is very workmanship dependent. It will be very difficult to transition this work to another vendor without a significant learning curve including numerous test builds of the hardware.

There is still some significant interface documentation that has not been completed and a relatively large percentage of subsystem detailed design drawings have also not been completed. It was stated that this work would be completed by August 2003.

Modal analyses with the new model indicated several fundamental frequencies below the minimum requirement of 50Hz. Several 45 degree lateral modes were identified at approximately 45 Hz. These modes will need to be further investigated, and, if accurate, may necessitate a waiver to the 50 Hz requirement. The Grid drum-head frequency (60 percent mass participation in the Z axis) was shown to be between 54.6 Hz and 48.5 Hz depending on how the calorimeter to grid interface is modeled. This modeling uncertainty needs to be resolved.

Some of the LAT Instrument and subsystem verification plans were not consistent. The LAT instrument should be exposed to "protoflight" levels for sine sweep, acoustics, and T/V testing, not "acceptance" levels as stated during the presentation. A LAT verification chart did not show some subsystems being exposed to sine sweep testing, yet the subsystem verification charts did show these tests.

Strength qualification plans of the Grid have been much better defined. However, the strength test still does not baseline using a set of S/C provided flexures which will ensure the correct load distribution into the Grid structure. Costs of the analyses and testing to justify the results without the use of the S/C flexures might be substantial.

There were several charts that showed a sine burst test of the full up LAT instrument to complete the qualification of the Grid. It would be highly desirable to fulfill all strength qualification requirements of the Grid during its subsystem level test and not expose the LAT instrument to a sine burst test. Sine burst testing is run open loop and is considered quite risky, particularly for this relatively large mass instrument. It may well be worth the extra effort to enhance the Grid strength qualification plans to cover all interfaces so that the sine burst test of the complete LAT instrument can be dropped.

A comprehensive stress report for the LAT primary structure and interfaces should be completed. It was clear that detailed analyses and stress determination work was in progress or planned, but complete results for the grid and other locations was not presented at this review.

Stress margins of safety for the CsI logs in the Calorimeter were presented using "average" structural properties from an old NASA report. However, this same report showed that the compressive strength of CsI varies widely. Analysis should either use the minimum properties from this report or additional testing should be conducted to determine compressive strength of the CsI material to be used for LAT. It was stated that additional structural tests would be conducted.

Actions need to be taken by System engineering to regain temperature margin in hot case. Radiator area cannot grow, therefore, margin must be "mined internally" and power dissipation must be capped at current levels (and preferably reduced).

The Tracker EM TV/TB tests, as well as the Xlat Heatpipe Panel/Electronics Thermal Joint EM tests are significant in establishing the viability of the thermal designs in these areas and are currently liens on the CDR presented design.

Another area of the analysis parameters that needs further refinement is the solar array thermal definition. A real solar array (vs. IRD solar array definition) has been evaluated with respect to its impact on LAT temperatures and shows a very positive result of 5° C on Tracker hot spot temperature. This should be pursued formally to further mine the real temperature margin in the design.

Consider redefining Tracker Temperature Limit from hot spot to an average of a number of trays. This may be a more meaningful requirement from a science perspective and it would provide a better measure of design margin. In addition, the use of the real Spectrum Astro solar array profile versus the IRD solar array definition will also result in a positive effect on the maximum Tracker temperature. A real solar array (versus IRD solar array definition) had been evaluated with respect to its impact on LAT temperatures and showed a very positive result of 5° C on Tracker hot spot temperature. This should be pursued formally to further "mine" the real temperature margin in the design.

Evaluate the addition of horizontal CCHPs to radiator panels to increase radiator efficiency, as well as other alternatives that will positively impact their rejection capability. Consider adding dual bore CCHPs (2) versus single bore CCHPs (2) on the Xlat Heatpipe Panel at the GASU location to mitigate significant over-temperature condition with a single bore CCHP failure. Consider characterizing Tracker performance (noise levels) during the Tracker Qual TV test over an extended upper range of +30° C to +50° C in addition to the planned workmanship screening at +50° C.

2.5.3 Recommendations

1. Enhance the strength qualification testing of the grid so that planned sine burst testing of the LAT instrument can be eliminated.

2. Conduct a delta review to address resolutions to the calorimeter to grid interface design, X-LAT plate thermal interface to the electronic boxes solution, and the EM Tracker Tower test results.

3. Provide a design option for the X-LAT Panel/Electronics interface that implements a hard-mounted, bolted connection versus the proposed flexible joint for this critical thermal interface.

4. Add over-temperature protection to the VCHP reservoirs. An over-temperature condition on the VCHP reservoirs could result in a catastrophic failure of the heatpipe, as well as the radiator panel.

5. Provide Spectrum Astro with the detailed thermal math model (TMM) for use in the Observatory level STOP analysis.

6. Provide a more comprehensive review of the electronic box level thermal/mechanical design and analysis. As a minimum, provide for each electronics box, a summary of all the powered part (resistors, diodes, ICs, ASICS etc.) temperature predictions vs. their derated part temperature limits. Standard NASA electronic box thermal analysis reports are available for review to better understand the scope and content of such analysis.

2.6 Systems Engineering (WBS 4.1.2)

2.6.1 Findings

The Systems Engineering activity has progressed significantly since the GLAST LAT PDR and Delta PDR but some areas were not at a Critical Design Review level of maturity.

The SLAC commitment to Systems Engineering has been significantly enhanced with the addition of Dick Horn as the full-time Lead Systems Engineer and Lowell A. Klaisner as the LAT Chief Engineer, who, although not explicitly part of the LAT Systems Engineering Team, performs many systems engineering functions. The addition of Dick Horn as Lead Systems Engineer has also allowed Tim Thurston to focus his part-time support on key critical areas like Reliability Engineering, FMEA's, FTA's, etc.

The GSFC commitment to Systems Engineering has been enhanced with the recent addition of Jack Leibee as the Systems Manager. This should provide the LAT Systems Engineering Team with a reliable, experienced, knowledgeable point of contact at the Mission Systems level.

The LAT Systems Engineering budget has also been enhanced with an additional $1.8 million for manpower. There has been no threat to Systems Engineering activities funded under other WBS numbers and all necessary activities seem to be taking place. Systems Engineering funding seems to be appropriate for the current effort and schedule. The schedule appears to be threatened from several quarters and the LAT Systems Engineering Team will have to be flexible to accommodate the inevitable changes.

While documentation maturity has improved substantially since PDR, with only 65 percent of the drawings released and many ICD's not yet complete, it is still far below a typical CDR level of maturity.

Margins are being tracked consistently for all appropriate areas with the exception of thermal margins (and magnetics margins depending on the magnetic contamination budget).

The LAT Instrument Performance Verification Plan (LAT-MD-00408-01) is in generally excellent shape for CDR but should be thoroughly reviewed with GSFC and Spectrum-Astro.

2.6.2 Comments

An outstanding Systems Engineering Team is in place and is sufficient in skill, experience, and numbers to adequately monitor and control all the Systems Engineering functions, tasks, and activities.

RFA's and recommendations from the PDR, Delta PDR, and Subsystem Peer Reviews appear to have been addressed seriously, courteously, professionally, and in sufficient detail. Many were covered in charts during the CDR presentations.

Subsystem and ICD working groups have been formed and appear to be working nominally.

The quality of the work on the Failure Modes and Effects Analysis appears to be excellent but a great deal of work needs to be done to complete this analysis for the entire LAT Instrument. The FMEA's have had some positive influence on the design but late completion reduces the chances of further influencing any remaining design decisions.

A Continuous Risk Management System is in place and is actively maintained and updated.

CDR presentations were inconsistent in the level to which they indicated how their designs meet the governing requirements, but a complete Requirements Verification Traceability Matrix is being completed under LAT Systems Engineering Team auspices.

2.6.3 Recommendations

All recommendations should be completed within the next three months.

1. The LAT Systems Engineering Team should organize and conduct a thorough review of the Failure Modes and Effects Analysis along with GSFC Mission Systems Engineering and the GLAST Spacecraft Contractor Spectrum-Astro.

2. The LAT Systems Engineering Team should ensure that Worst Case Circuit Analyses are conducted for all critical electronic circuits and assemblies to show that the electronics can perform to instrument and mission specifications over its full temperature, voltage, and current

conditions for the life of the mission. NASA JPL Preferred Reliability Practice PD-ED-1212 is a suggested guideline for performing these analyses.

3. The LAT Systems Engineering Team should ensure that there is a reliable Fault Management Design for LAT that is fully integrated and compatible with the Spacecraft and Observatory requirements and designs. LAT Fault Management Requirements and their methods of verification need to be defined. Any requirements for Spacecraft monitoring and management of LAT faults needs to be fully defined in the SC-LAT ICD.

4. The LAT Systems Engineering Team should ensure that an acceptable plan and schedule for completion of Engineering Drawings and ICD's that is sensitive to need dates and the Project Critical Path is generated by Design Integration. The drawing completion and release metrics should be monitored closely by the LAT Systems Engineering Team, as well as Design Integration.

5. The LAT Systems Engineering Team should participate in reviews of the software detailed designs, packages, algorithms, and flight code to ensure that they meet systems, as well as software requirements.

6. The LAT Systems Engineering Team should ensure that the impact of structural and thermal distortions on LAT pointing knowledge error is fully evaluated and understood. LAT Systems Engineering should ensure that the necessary models (thermal, mechanical, etc.) and support are provided to Spacecraft Provider Spectrum-Astro to complete the Observatory-level STOP Analysis.

7. The LAT Systems Engineering Team needs to include thermal margins among the many margins it is tracking.

8. Any requirements for magnetic cleanliness, magnetic contamination, and associated margins should also be tracked.

9. The LAT Systems Engineering Team should be closely monitoring the major problems areas (e.g. Thermal, Mechanical, SC-LAT Interfaces, ASIC's, true need for Sine Burst at Instrument Level, drawing and ICD completions, etc.), not just monitoring the risk list. (They appear to be using the Risk Management System as a proactive tool as of CDR.).

2.7 Integration and Testing (WBS 4.1.9)

2.7.1 Findings

The Integration and Test (I&T) subsystem is responsible for final assembly and testing of the LAT. This includes developing I&T plans and procedures, the mechanical ground support equipment and some elements of the electronics ground support equipment. The I&T subsystem will functionally test the LAT using beam tests and extensive functional testing at SLAC and other venues throughout the I&T phase. This subsystem is also responsible for environmental testing of the LAT instrument and will support observatory level integration and environmental test.

The cost for the I&T subsystem is $6.6 million. Contingency of $1.7 million (34 percent) is also budgeted. Cost to date is $1.6 million, which is appropriate given the work completed. The subsystem is on budget and on schedule according to the PMCS and is at a technical readiness level appropriate for CDR, CD-3, Approve Start of Construction. A total of $2.3 million in support from other subsystems is budgeted during the I&T phase although a detailed work plan for this support has not yet been generated. The basis of the cost estimates, the cost to complete, and the contingency appear adequate although the subsystem is obviously sensitive to slips in the deliveries from any of the other subsystems.

Many of the required plans are completed and awaiting approval by other subsystems. The master integration and test plan is in draft form. Test procedure writing has not yet commenced although it is correctly accounted for in the budget and schedule. All procedures must be complete by the time of the Integration Readiness Review (IRR) currently scheduled for December 2003.

There are at least two missing requirements documents that prevent finalization of I&T documentation. The dynamics test plan from the mechanical subsystem can not be completed until the mechanical design is finalized. The muon alignment procedure awaits input on actual muon rates for the LAT's thermal-vacuum configuration. The rates will determine the actual time required for the seven muon surveys required during the I&T phase.

Instrument I&T (including final assembly, LAT functional and environmental testing) is scheduled for June 2004 through May 2005. Assembly is planned to be complete in November 2004 and will be followed by three months of functional testing. Environmental test is scheduled for February-May 2005. The beam test, originally scheduled for the beginning portion of the I&T effort has now been decoupled from that activity and will be performed on the Calibration Unit (CU) after LAT I&T is complete. Environmental testing will be performed at the Naval Research Laboratory (NRL) facility. Observatory I&T will take place at the spacecraft vendor's facilities in Gilbert, Arizona and will be supported by the I&T subsystem.

The I&T building (SLAC Building 33) is complete. The 100,000 class cleanroom, LAT assembly area, and subsystem integration area are in place. A new "dry" sprinkler system is in place throughout the I&T area. Access systems and controls are in place. The cleanroom is fully operational.

The proposed airplane flight to NRL is no longer part of the project baseline but is retained as a risk mitigation activity and could still be used for an instrument systems level functional test. This test provides a count rate environment close to that expected on and is still viewed by the I&T team as a crucial demonstration of system level functionality. A study of the impacts of this test, including the vibration requirements imposed on the other subsystems will be complete by November 2003 and will be submitted to project management for a final decision on whether this test will be performed.

Thermal cycling of the entire LAT, originally planned as a workmanship verification, will no longer be performed at SLAC.

The I&T team currently plans to ship all MGSE, as well as EGSE, to NRL during the instrument environmental test period. This risk mitigation action will allow replacement of a tower while at NRL.

The I&T team has concern that the spacecraft simulator may not provide a wholly accurate representation of all interfaces. In particular the team is concerned about the lack of redundant power channels and microsecond level timing. There may be an impact on the I&T effort if it is determined that extra EGSE is needed in order to properly verify the S/C interface.

The primary risk to the I&T schedule continues to be late subsystem delivery. The most serious other risk is associated with a deintegration and replacement of a tower module. This procedure would cost $150 K and take approximately 40 days.

There are mission level magnetic field requirements on the LAT in the MAR. Magnetic test requirements have not yet flowed down into the test requirements. The capability to do those tests exists at NRL but this testing is not in the baseline plan.

Weldments are currently planned for some lifting fixtures, primarily due to tight overhead clearances provided by the current crane. This constraint leads to small (two-inch) clearances during assembly that are of some concern.

The I&T subsystem may incur additional scope due to an imposed requirement to simulate the spacecraft during acoustic testing.

2.7.2 Comments

The continued addition of personnel with space integration experience through the planned integration technician hires is a positive move that significantly decreases risk.

Continuing close coordination between SLAC, NRL and the hardware subsystems is essential to ensure a smooth flow through environmental testing.

It is noted that the weldments will require additional certification and inspection which may have significant cost and schedule impact. It may be worth considering alternate approaches including material changes.

2.7.3 Recommendations

1. Complete the overall I&T plan document by June 15, 2003, and generate a list of all required procedures and their "need by" date.

2. Complete the manpower plan for I&T by August 1, 2003, and obtain formal agreement from the subsystems supplying resources during I&T.

3. Modify the test plan documents by August 15, 2003, to reflect verification of the magnetic field requirements.

4. Finalize the I&T test schedule by September 1, 2003, taking into account the completed muon rate calculation, any conditions imposed by the magnetic field requirements and the final dynamics test plan.

5. Clarify the technical requirements and additional scope involved with producing a spacecraft simulator for the acoustic testing by September 15, 2003.
6. Review the design of the lifting fixtures against the relevant NASA standards for critical lifting fixtures by July 1, 2003, and determine whether other approaches would be appropriate.

2.8 Performance and Safety Assurance (WBS 4.1.A)

2.8.1 Findings and Comments

Performance and Safety Assurance (WBS 4.1.A) scope includes the efforts of the SLAC/LAT Performance Assurance Manager; development of a ISO 9000 compatible non-conformance reporting system, conducting Quality Assurance (QA) Audits for hardware and software, management of various QA support contracts, training of personnel to NASA work standards, LAT Safety Engineering, and support of the EEE parts program at NRL.

The cost as presented is $1.6 million, with an additional $0.1 million (18 percent) of contingency. There is considerable contributed labor from other subsystems and off-project. This cost and contingency is adequate. The subsystem has made excellent progress and is at the CDR, CD-3, Approve Start of Construction, level.

GFSC performed a follow-up survey of the LAT Performance Assurance System in December 2002, with no deficiencies noted in this survey. The observation of greatest concern is the requested identification of a single point of control for contamination control activities.

The Performance Assurance Manager's QA efforts will be augmented by a GSFC project-supplied quality engineer who reports directly to the project office. The subsystem manager will work with this individual to ensure a smooth division of responsibilities. The project has recently added a manufacturing engineer whose work has already been of direct and significant impact on the P&SA effort. The procedures appear to be robust and complete although the detailed cost impacts of these procedures was not presented.

A robust EEE parts program is in place and staffed. Most parts have been, or shortly will be qualified.

The P&SA manager has been actively involved with the LAT project for some time, and continues to have a good working relationship with his colleagues. He plays a key role in the project and depends on a great deal of support from other subsystems to accomplish his job.

2.8.2 Recommendation

1. Develop a workforce plan, by August 1, 2003, that specifically accounts for the effort required to support the new manufacturing and inspection procedures.

2.9 Ground Systems and Analysis (WBS 4.1.B and 4.1.D)

2.9.1 Findings

The Instrument Operations Center (IOC), WBS 4.1.B, scope includes the receipt and processing of Level 0 data telemetry packets from the Mission Operations Center (MOC), generation of Level 1 data products, build and verification of commanding plan for the LAT instrument, monitoring, and verification of instrument performance and trending and local archiving of both Level 0 and Level 1 products. The Science Analysis Software (SAS) sub-system, WBS 4.1.D, scope includes the Data Pipeline including Prompt processing of Level 0 data through to Level 1 event quantities, providing monitoring information to the IOC, instrument calibration, reprocessing of data, and the creation of high-level science products. The SAS subsystem also provides the interface to other sites, including the SSC and supports all engineering model and calibration tests.

The cost for the IOC as presented is $2.5 million, with an additional $0.44 million (22 percent) of contingency ($0.5 million has been spent to date). The IOC subsystem manager is not permanent and a search is underway for a permanent manager. The current subsystem manager is paid by the systems engineering subsystem (4.1.2). Due in part to the lack of permanent staff the IOC subsystem is spending well below baseline budget. This is expected to continue through CDR for this subsystem. As planned at the project baseline the IOC CDR is currently scheduled for February 2004. The schedule and cost as presented is reasonable for this stage of development. The final site of the IOC has not been determined, possible sites are Stanford campus and at SLAC.

The cost for the SAS subsystem is $3.6 million with an additional $0.53 million (22 percent) of the IOC is off-project. The subsystem manager coordinates and continues to encourage this off-project effort.

This contributed effort is expected to continue at or above the current level through the end of the project. The SAS subsystem is scheduled for subsystem CDR in February 2004 but is at or beyond CDR level at this time.

The coordination between the IOC and SAS subsystems and their counterparts at GSFC has suffered due, in large part, to the lack of a spacecraft vendor selection and the resultant lack of software and database standards. The selection of Spectrum Astro and recent coordination efforts by the team has begun to address this issue.

The primary effort of the acting IOC subsystem manager has been to write LAT operations and ground systems plans. The main efforts of the SAS subsystem have been continued development of the data pipeline to support the data challenge. This effort appears to be on schedule and will provide a valuable check on the science analysis efforts

Archiving of all Level 0, Level 1, final products and the software necessary to produce these products will be archived by the SAS subsystem. A separate archive will be maintained by GSFC in concert with the High Energy Astrophysics Science Archive and Research Center (HEASARC). Because of the complicated nature of the data the tools developed by SAS are not HEASARC compliant. Support for science users outside the LAT collaboration will be provided by the SSC whereas those within the collaboration will be supported by the SAS.

An external review committee has been commissioned by the PI and Project Scientist to evaluate the science analysis software efforts. The first step of this review, performed by telecon, resulted in a report that had some useful suggestions. The second meeting of this external review panel, to be held in the fall, could provide valuable additional input to the science analysis software effort.

2.9.2 Comments

The IOC manager has been in an acting role for almost one year. The lack of a full-time permanent manager to take long-term ownership of the subsystem is viewed by all relevant subsystem managers as damaging to the IOC effort.

The plans for how the continually evolving science analysis code is integrated into the IOC are not yet final. One solution, suggested by the IOC subsystem manager, is the establishment of a LAT

Operations Steering Committee (LOSC). Whether this, or some other, coordination mechanism is adopted it does appear clear that some additional management structure would be useful.

The use of LTX for the flight software test and verification program creates additional complexity for the software, I&T and operations efforts. The details of how the flight software command and telemetry database will translate into the I&T database are not yet clear, nor has this process been demonstrated. Further, there seems to be no capability for leveraging LTX test procedures in the I&T EGSE environment. Surely, the flight software team will be producing valuable work that should be retained. Duplicating software tests at the I&T level will be unwise.

2.9.3 Recommendations

1. Hire a permanent IOC manager in time to support the data challenge now scheduled for fall 2003.

2. Define the process and operating practices for the use of the science analysis software by July 15, 2003, including the suggested LOSC as a potential structure.

3. Initiate regular coordination meetings between flight software, I&T, IOC and GSFC by the end of June to continue the process of defining how the software and database efforts will work.

4. Define a common architecture for the flight software and I&T command and telemetry databases by September 1, 2003, or define a process for translating a flight software database to the I&T format.

5. Create a mechanism for interpretation/translation of LTX test procedures within the I&T EGSE environment by August 1, 2003. Alternatively, allocate staff and schedule to identify relevant software test procedures that are useful for I&T and task the staff with re-creating the flight procedures.

3. COST, SCHEDULE, and FUNDING (WBS 4.1.1)

3.1 Cost

3.1.1 Findings

The LAT budgeted cost to completion has now increased to $107.46 million (actual-year) with available contingency of $14.25 million (actual-year). This represents a 7.5 percent increase over the original LAT cost estimate ($99.97 million) with the largest cost changes found in Instrument Management (4.1.1), System Engineering (4.1.2) and the Anti-Coincidence Detector (4.1.6). Approximately $20 million of earned value has been accomplished since the baseline. Contingency as a fraction of cost to go is now 23.2 percent. The total project cost (TPC) remains fixed at $121.71 million (actual-year).

There are additional costs to the LAT project not yet captured in the approved cost estimate. These include overruns in Instrument Management (4.1.1), Anti-Coincidence Detector (4.1.6), known items in the Tracker (4.1.4), and an open commitment under negotiation with Lockheed Martin estimated by the committee at $1.6 million.

In April 2003, CNES, the French agency funding the LAT CDEs announced that it would withdraw its commitment to the LAT project. LAT management has proposed a fallback plan that would require $3.2 million (actual-year) base cost plus contingency (30-50 percent). LAT management does not expect a schedule impact if the fallback plan is implemented soon.

LAT management has implemented a Project Management Control System (PMCS), and has been reporting cost and schedule performance using an earned value system since September 2001. The PMCS team is working well utilizing Primavera P-3 as the primary schedule database tool, complemented with COBRA for handling the approximate 225 actual cost work packages for the LAT project.

This strong set of tools is sufficient to providing LAT management with real quantifiable performance on the LAT project, and for external output to NASA and DOE reporting. Change requests are approved by the LAT line management LAT Change Control Board (CCB) and contingency allocation is tracked from baseline to date.

The PMCS team is currently comprised of three full-time SLAC employees supported by a team of 2.5 FTE consultants from Applied Integration Management. LAT management has costed this blended team throughout the fabrication phase of the LAT (September 2005). The PMCS team may be reduced in the later stages of the project, as the work volume (number of open work packages) decreases.

3.1.2 Comments

The Committee was very impressed with LAT management and the PMCS group and thanks them for their thorough presentation and frank discussion of the present status and future challenges of the LAT project.

The reduction of available contingency to cost to go from 29 to 23 percent is a concern, particularly given that contingency allocation to work accomplished is approximately 35 percent since baseline. While the Committee acknowledges that past contingency allocation does not necessarily extrapolate linearly, the LAT has yet to enter the manufacturing, which is then followed by an I&T phase, such that the available contingency does not appear adequate to support the LAT through the complete fabrication phase.

Attempts to introduce descoping scenarios in order to provide cost and schedule flexibility are apparently not feasible without seriously impacting the scientific mission of LAT.

3.2 Schedule and Funding

3.2.1 Findings

The integrated resource-loaded cost and schedule baseline for LAT consists of approximately 8,300 schedule activities, with a budget cost to completion of $107.46 million (DOE, NASA, and Japan funding), and contains approximately 190 interface milestones that are consistent with a LAT delivery to NASA in September 2005. The DOE CD-4 milestone date for the completion of the LAT fabrication project is March 15, 2006.

LAT management presented high-level critical path analyses for the overall LAT, as well as for each LAT subsystems. The overall LAT schedule provides for 17 weeks of overall float. The critical path of the LAT is currently the Calorimeter Detector Elements (approximately three weeks of float), followed by the I&T of the LAT instrument, with a final 14 weeks of explicit float prior to delivery of the LAT on September 22, 2005. Electronics module assembly was also found to be very near the critical path.

Schedule performance against the baseline is approximately 93 percent. Given the slip in schedule, LAT management has recently moved the planned beam test off the critical path, thus preserving the 14 weeks of explicit slack after I&T. This recent change to the schedule baseline has not yet been incorporated in the LAT PMCS.

Cumulative planned work through FY 2003 will saturate available funding, and assuming the work is fully committed, leaves no available funding contingency for solving problems or maintaining schedule.

Table 3-1 LAT DOE & NASA Cost Estimate through March 2003

Cost Estimate (Actual Year k$)				
WBS#	**Subsystem**	**Cost To Date**	**Cost To Go**	**Total Base Cost**
4.1.1	Instrument Management (SC7/8)	$7,285	$8,072	$15,357
4.1.2	System Engineering (SC4)	$3,029	$3,424	$6,453
4.1.4	Tracker (SC1)	$6,630	$4,285	$10,915
4.1.5	Calorimeter (SC1)	$7,372	$10,458	$17,830
4.1.6	Anti-Coincidence Detector (SC1)	$6,790	$4,767	$11,557
4.1.7	Electronics (SC2)	$4,828	$11,844	$16,672
4.1.8	Mechanical Systems (SC3)	$3,735	$6,638	$10,373
4.1.9	Instrument Integration & Test (SC5)	$1,612	$4,976	$6,588
4.1.A	Performance & Safety Assurance (SC5)	$729	$878	$1,607
4.1.B	Instrument Operations Center (SC6)	$262	$2,250	$2,512
4.1.C	Education & Public Outreach (SC10)	$746	$1,938	$2,684
4.1.D	Science Analysis Software (SC6)	$1,093	$2,502	$3,595
4.1.E	Suborbital Flight (Balloon) Test	$1,325	-$4	$1,321
Subtotals		**$45,436**	**$62,028**	
LAT Estimated Base Cost				**$107,464**
LAT Total Project Cost				**$121,713**
Contingency				**$14,249**
Contingency on Cost-to-Go (%)				**23%**

3.2.2 Comments

Given the delays to the "ambitious" baseline schedule and the large fraction of work yet to go, the Committee found the LAT baseline schedule to be in doubt. While 17 weeks of explicit slack appears substantial, this provides only approximately 17 percent of schedule slack over the remaining two years of the LAT fabrication phase. With the number of open design issues and reduction in contingency, the LAT schedule is vulnerable to additional delays during the manufacturing and I&T phases of fabrication.

LAT management has been proactive in maintaining the 17 weeks of explicit slack (beam test off the critical path) and for adding integration and engineering manpower to the LAT project. However, the success of the LAT project is dependent upon the delivery of the LAT within its baseline cost and schedule. Given the LAT's lack of scope, cost, and schedule flexibilities, LAT management is strongly urged to develop additional work around strategies into its cost and schedule work plan (e.g., an approximate four-month delay in the mechanical grid) to keep to the schedule.

Table 3-2 LAT DOE & NASA Funding Estimate (Escalated M$) *

	FY00	FY01	FY02	FY03	FY04	FY05	Total
DOE	3.00	5.69	8.08	8.91	7.90	3.42	37.00
NASA	3.86	3.85	13.14	20.92	25.80	15.67	83.24
JAPAN	0.00	0.00	0.00	0.00	1.00	0.00	1.00
Total/FY	6.86	9.54	21.22	29.83	34.70	19.09	121.24

***Subject to change pending resolution of CNES funding issue.**

3.3 Recommendations

1. Update the LAT cost estimate to complete the project including a detailed contingency analysis, taking into account the additional costs cited in this report by August 1, 2003.

2. Develop "work-around" strategies to address the risks cited in the previous sections and to add flexibility to the LAT cost and schedule planning

3. Update the PMCS schedule to reflect moving the beam test out of the critical path.

4. MANAGEMENT (WBS 4.1.1)

4.1 Findings

4.1.1 Overall Management

Overall, the LAT Project Management team appears to be working well. Staff assignments and management documentation are stable; management tools are mature and effectively used. Communication with program and project managers at the funding agencies is good. Reorganization and new staff in Instrument Design Engineering and System Engineering appears to have had a positive effect on the management of the project.

4.1.2 Risk Management

Project Management is dealing appropriately with cost and schedule risk through the allocation of contingency and though schedule modification. Examples include the rapid response to the very recent CNES default on its commitments to the calorimeter subsystem and the rescheduling of the beam test effort in response to the calorimeter schedule.

4.1.3 International Issues

The International Finance Committee had its first meeting in February. The situation with French funding commitments was not known at the time of that meeting. SLAC and LAT management are paying appropriate attention to the situation of the Italian collaborators as well, since there are agency-laboratory and agency-agency letters of agreement that are not signed. SLAC and LAT management do not view this situation as a problem at this time.

4.1.4 Conceptual Design Review/Critical Decision-3 Readiness

The fabrication readiness of the individual subsystems is discussed in Section 2 above. Overall, they range from “already in fabrication” to “design phase,” with fabrication drawings about 65 percent complete. Recent peer reviews of the subsystems resulted in about 180 RFA from the review committees; these are being closed out at a good rate; about 80 remained to be closed out as of the date of this review.

4.2 Comments

4.2.1 CNES

The problems caused by the CNES default are very serious, in terms of both cost and potential schedule impact. The situation appears to have been well handled so far; LAT management acted quickly and decisively to implement a workaround that involves moving effort (and cost) to the U.S. In the short-term this action is backed by available LAT contingency. The workaround is said to have no impact on the schedule, but it is too early in this rapidly evolving situation to judge. However, this cannot be regarded as a problem to be addressed in the long-term with LAT contingency—certainly not with LAT budget contingency and maybe not with LAT schedule float. The CNES problem ultimately needs a solution at the funding agency level.

4.2.2 Beam Test

The rescheduling of the beam test until after the delivery of the instrument was an excellent response to the increased risk due to delays in the engineering model of the calorimeter. This may not have completely mitigated that risk, but it was an inspired change that also has other benefits.

4.2.3 Schedule and Contingency Management

The Committee found that the present schedule for delivering the LAT is aggressive and the remaining contingency is light. As presented, the schedule float in the project is 17 weeks, owned by management. The subsystems themselves own little or no schedule float. Contingency as a fraction of costs to go was shown as 23 percent, which is less than the contingency use rate since the PDR (35 percent). The 23 percent does ***not*** include covering the CNES problem or any existing liens against contingency. Whether the schedule is doable or the remaining contingency is adequate can be debated; the Committee is uncomfortable with both.

New elements of the project schedule are not yet reflected in subsystem milestones. This caused some disconnects among presentations and breakout discussions but is not a problem—Project Management is planning to update the PMCS within about a month after this review.

4.2.4 Conceptual Design Review/Critical Decision-3 Readiness

Application of the criteria for CDR and/or CD-3 approval is something of an art, since the LAT components are in various states of readiness to fabricate. On one hand, long-lead time purchases of flight components are under way; on the other, there are significant unresolved design issues. This is typical of large complex detectors. DOE requirements for CD-3 approval are shown in Table 4-1. NASA requirements for CDR approval are shown in Table 4-2. The committee found that these requirements are met with some exceptions.

Table 4-1. Current Status of DOE CD-3 Requirements

CD-3 Requirement	Status
Update Project Execution Plan (PEP) and performance baseline	Updating of PEP in progress, waiting for CD-3/CDR recommendation in order to update performance baseline.
Final design and procurement packages **(**)**	Procurement proceeding in accordance with Acquisition Execution Plan. Waiting for CD-3/CDR review recommendations regarding adequacy of final design package.
Verification of mission need	Currently schedule for July 15, 2003
Budget and congressional authorization and appropriation enacted	N/A - Funded out of MIE
Approval of Safety documentation	Operation and Support Hazard Analysis (OSHA) document has been finalized by project, 5/7/03. Once submitted to DOE will coordinate review and approval with SC-83.
Execution Readiness Independent Review	Taking place via CD-3/CDR review.

Table 4-2. Status of NASA CDR Requirements

CDR Requirement	Status
Complete Instrument design reviewed in full detail	Accepted with some exceptions in Mechanical Systems, Thermal Design and Software; Some incomplete drawings and interface control documents
Technical problems and design anomalies resolved	Accepted with some exceptions in Mechanical Systems and Thermal Design
Design maturity justifies the decision to initiate fabrication and manufacturing	Accepted with exceptions to the mechanical and thermal subsystems referenced in RFA #17. Concurrence to proceed with fabrication and manufacturing for these items are contingent upon acceptance of designs during the peer reviews specified in the RFA.

4.3 Recommendations

1. DOE should grant LAT CD-3 approval, contingent upon resolution of the cost and schedule issues addressed in the Recommendations in Section 3 above.

2. NASA should grant LAT CDR approval, contingent upon resolution of the exceptions addressed in the RFAs (Appendix E).

APPENDIX A

CHARGE MEMORANDUM

TO: Daniel Lehman, Director, Construction Management Support Division, SC-81

Date: APR 1 8 2003

RE: NASA Critical Design Review (CDR) and DOE Start of Construction Review (CD-3) of the Large Area Telescope Project

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The Large Area Telescope (LAT) is the principal scientific instrument to be flown on the National Aeronautics and Space Administration (NASA) Gamma-ray Large Area Space Telescope (GLAST) Mission, scheduled for launch in 2006. As part of the oversight of the LAT project, the Division of High Energy Physics requests that you co-chair a Start of Construction (CD3) review jointly with the NASA Critical Design Review (CDR), using an independent review team. This review has been scheduled for May 12 through May 16, 2003, at the Stanford Linear Accelerator Center (SLAC).

At the joint DOE and NASA review held in July 2002, the review team recommended approving the LAT project for preliminary design review (PDR) and baseline status. The NASA PDR status is focused on the technical design of each subsystem and the integrated instrument in addition to being concerned with the cost, schedule, and management structure. The DOE baselining status is focused on the technical design, cost, schedule, and management structure of the subsystems as well as the entire project. Quarterly status reviews, held in November 2002 and January 2003, highlighted unresolved technical issues and schedule delays in several subsystems, as well as the corrective action plan put in place to resolve these issues.

The purpose of the upcoming review is to carry out an integrated examination and assessment of the final design of the entire project, in anticipation of the start the of fabrication. The committee should evaluate the project, keeping in mind changes since PDR and baselining approval as well as issues highlighted in past reviews.

In carrying out its charge, the review committee should address the following specific items:

- Review and evaluate the complete system design. Is the maturity of the design and development effort appropriate and does it justify supporting the project to proceed with full scale fabrication activities?

- Is the technical, cost, and schedule status of the project consistent with the baseline objectives and is the project progressing adequately? Is the information in the LAT Project Management Control System and the DOE Project Assessment Reporting System consistent with physical progress?

- Are the Project's risks being managed effectively?

- Is the management structure adequate and appropriate for guiding the project to completion?

Kathleen Turner is the DOE program manager for the LAT project and will serve as the DOE point of contact for the review.

A formal review report is requested to be sent to the DOE Division of High Energy Physics by July 15, 2003.

We appreciate your assistance in running this review. As you know, these reviews are an important element of the DOE oversight of the GLAST/LAT Project. They help to ensure that the project meets its commitments to keep the GLAST/LAT science program robust.

Robin Staffin
Acting Director
Division of High Energy Physics
Office of Science
U.S. Department of Energy

APPENDIX B

REVIEW PARTICIPANTS

Department of Energy/National Aeronautics and Space Administration Review
of the
GLAST Large Area Telescope (LAT) Project
May 12 - 16, 2003

Daniel R. Lehman, DOE Co-Chairperson

Mark Goans, NASA Co-Chairperson

SC1	SC2	SC3	SC4
Tracker, Calorimeter, Anti-Coincidence Detector (WBS 4.1.4; 4.1.5; and 4.1.6)	**Electronics, DAQ, Elec. Sys. & Flight S/W (WBS 4.1.7)**	**Mechanical Systems (WBS 4.1.8)**	**Systems Engineering (WBS 4.1.2)**
* Helmuth Spieler, LBNL	* Fred Heugel, GSFC	* James Ryan, GSFC	* Steve Scott, GSFC
Ron Ray, Fermilab	Chris Bebek, LBNL	Dick DiGennaro, LBNL	Joe Bolek, GSFC
	Ron Zellar, GSFC	Tom McCarthy, GSFC	

SC5	SC6	SC7	SC8
Integration and Testing Performance/Safety Assure. (WBS 4.1.9 and 4.1.A)	**Ground Systems/Analysis (WBS 4.1.B and 4.1.D)**	**Cost, Schedule and Funding (WBS 4.1.1)**	**Project Management (WBS 4.1.1 and 4.1.C)**
* Bill Craig, LLNL	* Bill Craig, LLNL	* Mark Reichanadter, Fermilab	* Sam Aronson, BNL
Bob Vernier, GSFC	Ron Zellar, GSFC	Steve Tkaczyk, DOE/SC	Mark Goans, GSFC
			Phillip Sabelhaus, GSFC

Observers

K. Turner, DOE/SC	A. Vernacchio, GSFC
E. Valle, DOE/SSO	D. Dillman, GSFC
K. Grady, GSFC	J. Wonsever, GSFC
S. Horowitz, NASA	A. Fuchs, GSFC
D. Kniffen, NASA	

LEGEND

SC Subcommittee
* Chairperson
[ ] Part-time Subcom. Member

Count: 19 (excluding observers)

06/19/2003:q:sc-81:sns:0010rev:revcmglast.xls

APPENDIX C

REVIEW AGENDA

LAT CDR/CDR Schedule (Draft 5)
May 12-16, 2003

Monday 5/12/2003			**LAT CDR/CD3 - Day 1**	
Section	**Start**	**Stop**	**Topics**	
	12:00 PM	1:00 PM	Executive Session	
	1:00 PM	1:05 PM	Welcome	J. Dorfan
	1:05 PM	1:10 PM	Opening Statement	Committee Chair(s)
1	1:10 PM	1:40 PM	Introduction & Science Overview	P. Michelson
2	1:40 PM	2:10 PM	Project Management (WBS: 4.1.1/SC10)	W. Althouse
			Break	
3	2:25 PM	3:15 PM	Science Requirements	S. Ritz
4	3:15 PM	4:00 PM	Instrument Design Overview	L. Klaisner
5	4:00 PM	4:20 PM	LAT Operations and IOC (WBS: 4.1.B/SC8)	D. Lung
6	4:20 PM	5:00 PM	Science Analysis Software (WBS: 4.1.D/SC8)	R. Dubois
	5:00 PM		Executive Session	
Tuesday 5/13/2003			**LAT CDR/CD3 - Day 2**	
Section	**Start**	**Stop**	**Topics**	
7	8:00 AM	9:30 AM	Systems Engineering (WBS: 4.1.2/SC6)	D. Horn
			Break	
8	9:45 AM	11:45 AM	LAT Design Integration	L. Klaisner
			Lunch	
	12:30 PM	2:30 PM	LAT Design Integration (Continued)	
			Break	
9	2:45 PM	5:00 PM	Tracker (WBS: 4.1.4/SC1)	R. Johnson
	5:00 PM		Executive Session	

LAT CDR/CDR Schedule (Draft 5)
May 12-16, 2003

Wednesday 5/14/2003			**LAT CDR/CD3 - Day 3**	
Section	**Start**	**Stop**	**Topics**	
10	8:00 AM	10:15 AM	Calorimeter (WBS: 4.1.5/SC2)	N. Johnson
			Break	
11	10:30 AM	11:45 AM	Anti-Coincidence Detector (WBS: 4.1.6/SC3)	D. Thompson
			Lunch	
	12:30 PM	1:30 PM	ACD Presentation (Continued)	
12	1:30 PM	2:45 PM	Electronics & DAQ (WBS: 4.1.7/SC4)	G. Haller
			Break	
	3:00 PM	3:45 PM	Electronics (continued)	
	3:45 PM	5:15 PM	Flight Software (WBS: 4.1.7/SC4)	G. Haller
	5:15 PM		Executive Session	
Thursday 5/15/2003			**LAT CDR/CD3 - Day 4**	
Section	**Start**	**Stop**	**Topics**	
13	8:00 AM	9:30 AM	Mechanical Systems (WBS: 4.1.8/SC5)	M. Campell
			Break	
	9:45 AM	10:45 AM	Mechanical (continued)	
14	10:45 AM	12:00 PM	Instrument Integration & Testing (WBS: 4.1.9/SC7)	E. Bloom
			Lunch	
	12:00pm	*3pm*	*Breakout/Splinter sessions as needed*	
	12:45 PM	1:30 PM	I&T (continued)	
15	1:30 PM	2:00 PM	Manufacturing Process	J. Clinton
16	2:00 PM	2:30 PM	EEE Parts Plan	N. Virmani
17	2:30 PM	3:00 PM	Performance & Safety Assurance (WBS: 4.1.A/SC7)	D. Marsh
	3:00 PM		Executive Session	
	5:30 PM	6:00 PM	Project Debrief	
	6:00 PM		Executive Session & Report Writing cont.	
Friday 5/16/2003			**LAT CDR/CD3 - Day 5**	
Section	**Start**	**Stop**	**Topics**	
	8:00 AM	10:30 AM	Executive Session & Report Writing	
	10:30 AM	11:30 AM	Closeout	Committee Chair(s)
	11:30 AM		Adjourn	

APPENDIX D

COST
TABLE

Budgeted Fabrication Cost

Budgeted DOE + NASA Costs for Fabrication Phase

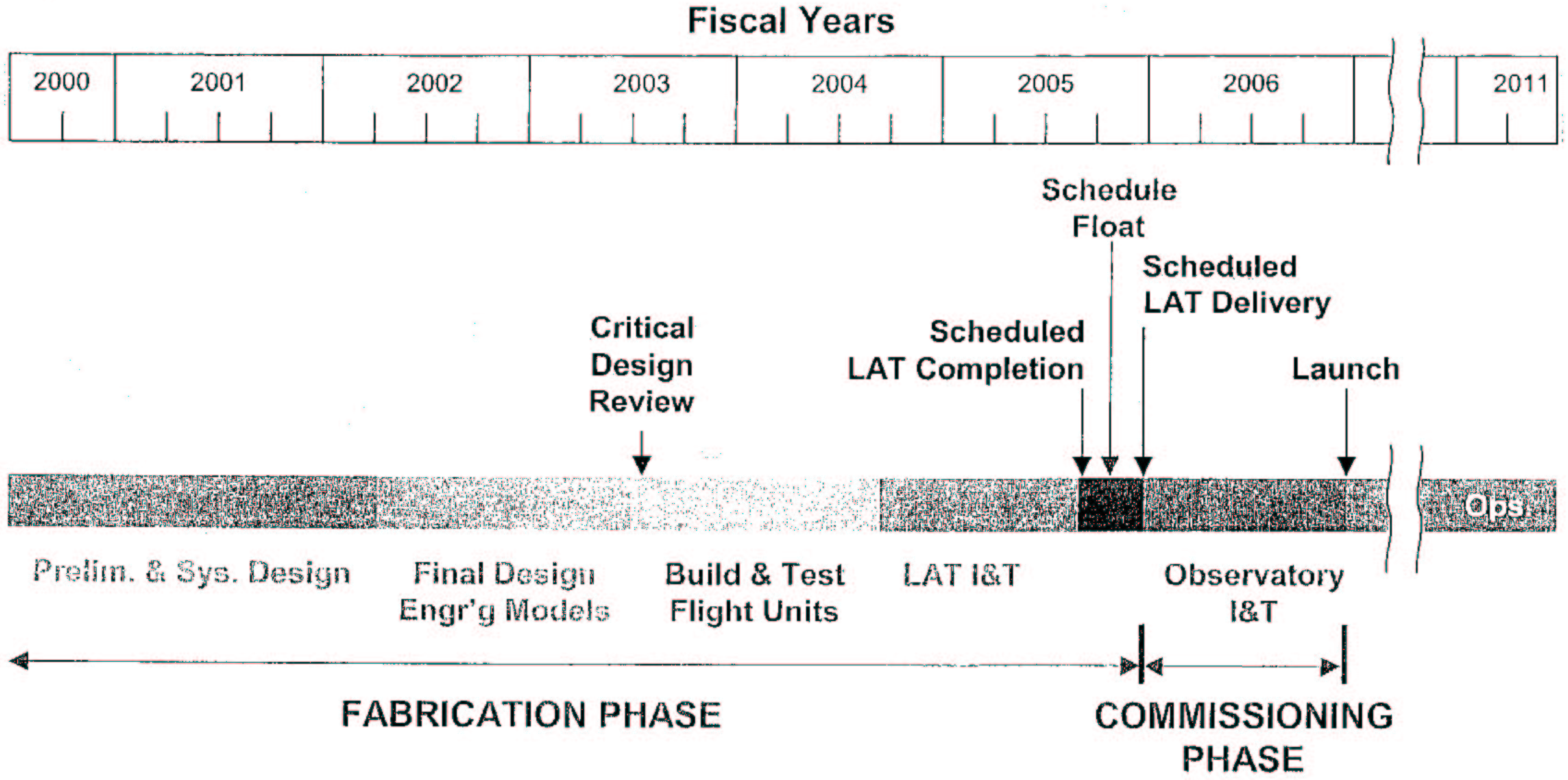
	(escalated $M)	
	Baseline	3/31/03
Budgeted Cost at Completion	100.0	107.5
Contingency	21.2	14.2
Total Estimated Cost (TPC=TEC)	121.2	121.7

	Baseline	3/31/03
Budgeted costs at risk	72.7	59.4
Contingency fraction	29%	24%

APPENDIX E

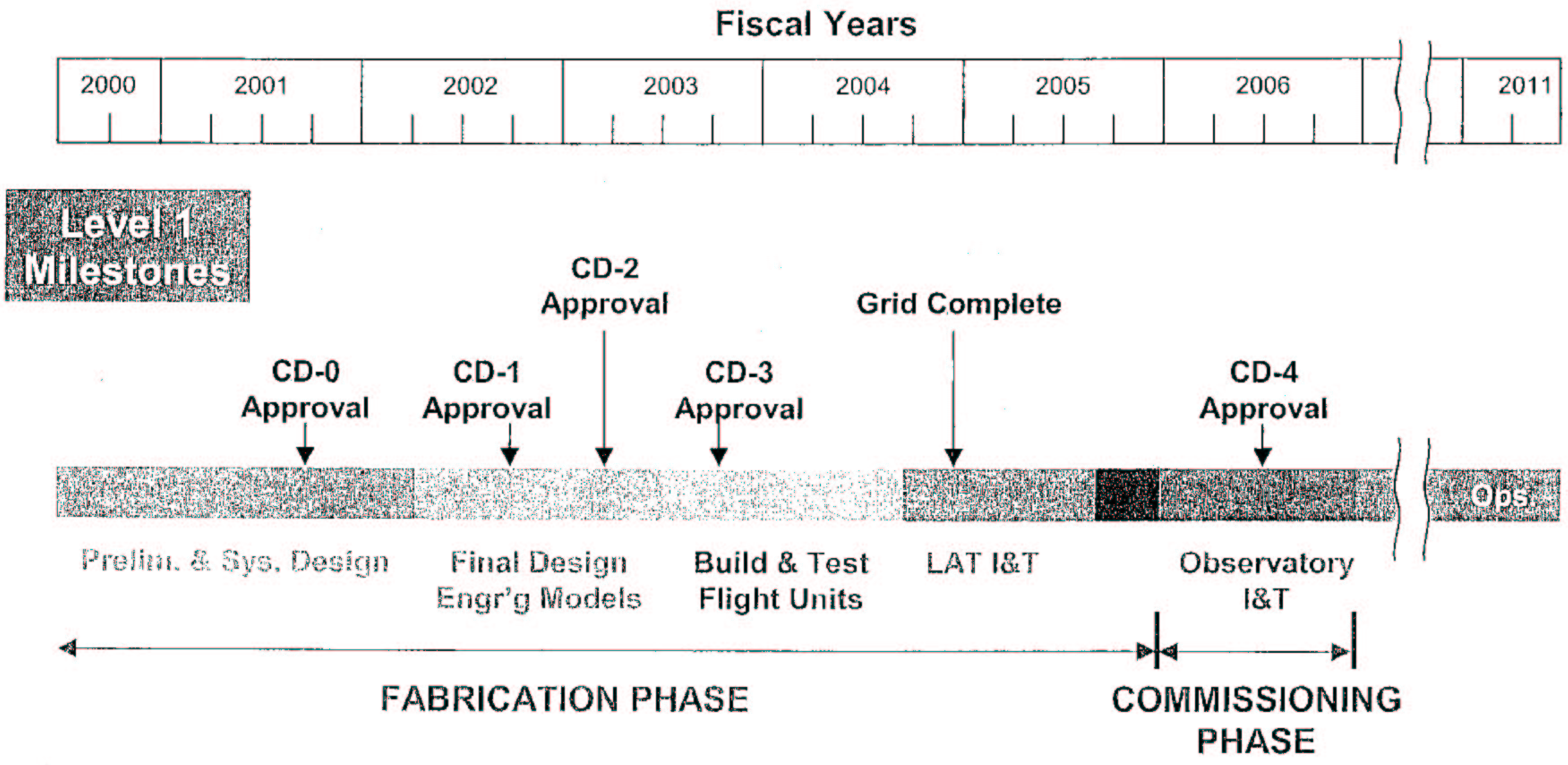
SCHEDULE CHARTS

Schedule Overview



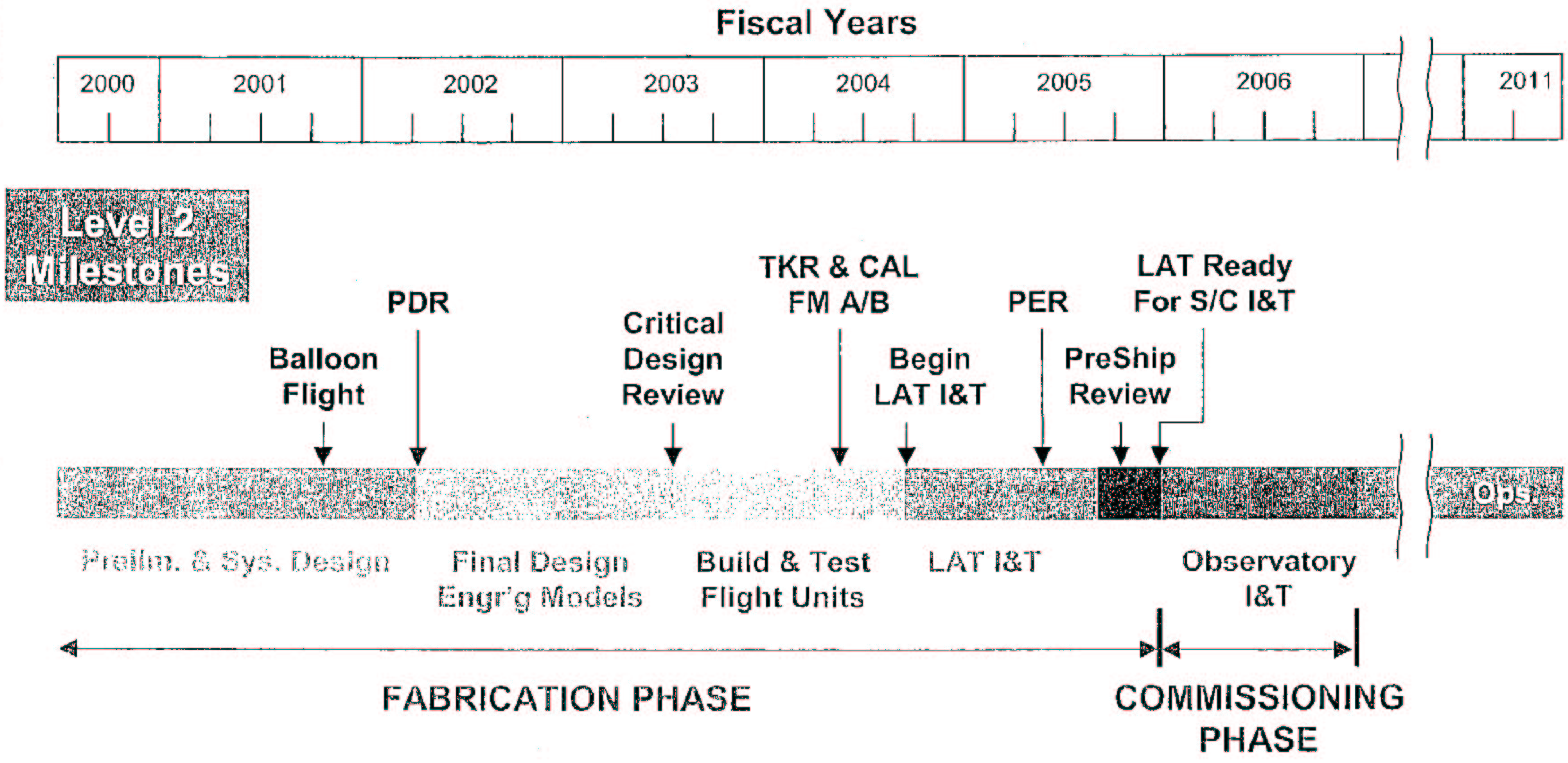
GLAST scheduled for launch in September 2006

Schedule Overview



GLAST scheduled for launch in September 2006

Schedule Overview



GLAST scheduled for launch in September 2006

APPENDIX F

NASA REQUESTS FOR ACTION

NASA Requests for Action

Request For Action **Number: 1**

Project	Gamma-ray Large Area Space Telescope (GLAST)
System/Instrument:	Large Area Telescope (LAT)
Review:	Critical Design Review (CDR)
Date:	May 12-16, 2003

Originator: Fred Huegel
Don Kniffen
Phone: 301-286-2285
Organization: GSFC/560

Category: Software

Title: On-orbit Performance of Event Filtering Software

Action Requested: Provide details of plans to assess the performance of the event filtering software on-orbit to maintain knowledge of the scientific responses of the LAT.

Supporting Rationale: Any event filtering system runs the risk of removing signal at a rate that can vary with time. Proper scientific analysis requires proper knowledge of the event filtering mechanisms.

Proj. Res:

Request For Action **Number: 2**

Project	Gamma-ray Large Area Space Telescope (GLAST)
System/Instrument:	Large Area Telescope (LAT)
Review:	Critical Design Review (CDR)
Date:	May 12-16, 2003

Originator: Fred Huegel
Phone: 301-286-2285
Organization: GSFC/560

Category: Electrical

Title: LAT Baseplate Mock-up to Manufacturer for Harness Fabrication

Action Requested: Provide a LAT baseplate mock-up to the harness manufacturer for harness fabrication.

Supporting Rationale: The LAT electrical system harness is a fairly complex one with tight spacing in areas. Wiring to a harness mock-up will provide the best fit harness with the least amount of stress at the connectors.

Proj. Res:

Request For Action **Number: 3**

Project	Gamma-ray Large Area Space Telescope (GLAST)
System/Instrument:	Large Area Telescope (LAT)
Review:	Critical Design Review (CDR)
Date:	May 12-16, 2003

Originator: Fred Huegel
Phone: 301-286-2285
Organization: GSFC/560

Category: EMI/EMC

Title: Conducted Emissions and conducted Susceptibility

Action Requested: Provide a conducted emissions and conducted susceptibility test as part of the box acceptance testing

Supporting Rationale:

Proj. Res:

Request For Action **Number: 4**

Project	Gamma-ray Large Area Space Telescope (GLAST)
System/Instrument:	Large Area Telescope (LAT)
Review:	Critical Design Review (CDR)
Date:	May 12-16, 2003

Originator: Fred Huegel, Scott Kniffin **Phone:** 301-286-2285, 301-286-1185 **Organization:** GSFC/560, GSFC/561

Category: Radiation

Title: Electrical Derating Criteria for MOS Transistors in the DAQ

Action Requested: What is the electrical derating criterion on MOS transistors in DAQ? What about the DC/DC converters? Are they qualified for total dose and single event?

Supporting Rationale: Derating is required by NASA standard on all electronics to be flown in the space environment. DC/DC converters not on parts lists that have been reviewed so far.

Proj. Res:

Request For Action **Number: 5**

Project	Gamma-ray Large Area Space Telescope (GLAST)
System/Instrument:	Large Area Telescope (LAT)
Review:	Critical Design Review (CDR)
Date:	May 12-16, 2003

Originator: Fred Huegel, Scott Kniffin **Phone:** 301-286-2285, 301-286-1185 **Organization:** GSFC/560, GSFC/561

Category: Electrical

Title: Qualification Method for MCM Burn In

Action: Produce the qualification method used to determine the burn in for the MCMs on Tracker.

Supporting Rationale: What qualification method requires 85 deg. C at 168 hours for burn in of MCMs on Tracker? This does not follow standard NASA burn in requirements.

Proj. Res:

Request For Action **Number: 6**

Project	Gamma-ray Large Area Space Telescope (GLAST)
System/Instrument:	Large Area Telescope (LAT)
Review:	Critical Design Review (CDR)
Date:	May 12-16, 2003

Originator: Fred Huegel, Scott Kniffin **Phone:** 301-286-2285, 301-286-1185 **Organization:** GSFC/560, GSFC/561

Category: Electrical

Title: Electrical Derating Criteria Used on ASICs

Action : What electrical derating criteria was used on the ASICs? Define and describe.

Supporting Rationale: ASICs are required to be derated by 20% per NASA SOP for ASICs. The parts would represent a higher risk to the mission if they were not derated for their application.

Proj. Res:

Request For Action **Number: 7**

Project	Gamma-ray Large Area Space Telescope (GLAST)
System/Instrument:	Large Area Telescope (LAT)
Review:	Critical Design Review (CDR)
Date:	May 12-16, 2003

Originator:	**Phone:**	**Organization:**
Fred Huegel	301-286-2285	GSFC/560
Chris Bebek	510-486-6447	LBNL

Category: Electrical

Title: Verification Plan for LAT Hardware and FSW Control of VCHP

Action Requested: Provide a verification plan for LAT hardware and flight software control of VCHP, including required LAT hardware and fight software support at Lockheed-Martin for VCHP testing.

Supporting Rationale: Lockheed will provide algorithm for processing greater than 100 temperature sensors into twelve "on" times for VCHP heaters. LAT electronics and flight software are responsible for control of the heaters. The plan for verifying electrical/flight software with VCHP was described.

Proj. Res:

Request For Action **Number: 8**

Project	Gamma-ray Large Area Space Telescope (GLAST)
System/Instrument:	Large Area Telescope (LAT)
Review:	Critical Design Review (CDR)
Date:	May 12-16, 2003

Originator: Ron Zellar **Phone:** 301-286-5842 **Organization:** GSFC/582

Category: Software

Title: Complete Selection Study of XML vs. MySQL

Action Requested: Complete any trade-offs for selecting a command and telemetry database meta-language and implement the database in the flight software test environment.

Rationale: This selection is needed to allow progress in instrument I&T, the IOC, spacecraft I&T/ mission operations.

Proj. Res:

Request For Action **Number: 9**

Project	Gamma-ray Large Area Space Telescope (GLAST)
System/Instrument:	Large Area Telescope (LAT)
Review:	Critical Design Review (CDR)
Date:	May 12-16, 2003

Originator:	**Phone:**	**Organization:**
Ron Zellar	301-286-5842	GSFC/582
Steve Scott	301-286-2529	GSFC/500
Ann Merwarth	239-415-2290	HQ/IRT
Ed Tadlock	304-368-8274	GSFC/IV&V

Category: Software

Title: Conduct Detailed Design Reviews

Action Requested: In the currently scheduled design reviews for EM2 and the FU builds, show detailed design information that includes the participation of independent reviewers, packages, algorithms and code walkthroughs.

Supporting Rationale: Design materials presented to date have been high level and preliminary. With the use of a spiral development process, it is critical to have reviewers remain up to date with the latest design issues.

Proj. Res:

Request For Action **Number: 10**

Project	Gamma-ray Large Area Space Telescope (GLAST)
System/Instrument:	Large Area Telescope (LAT)
Review:	Critical Design Review (CDR)
Date:	May 12-16, 2003

Originator: Jim Ryan **Phone:** 301-286-4975 **Organization:** GSFC/543

Category: Mechanical

Title: Eliminating Sine Burst Testing on Full Instrument

Action Requested: Enhance the strength qualification testing of the grid so that sine burst testing of the LAT instrument can be eliminated. It was stated that LAT sine burst testing was being considered to complete strength qualification of Grid and Tracker joint.

Supporting Rationale: Sine burst testing at the full instrument level is a very risky test. The test is run open loop and for such a large mass instrument there would be valid concerns that the test input can be accurately achieved. Also, strength qualification of the grid might "over-test" other components or subsystems of the LAT. An actual over-test (input loads exceeded) could be very damaging to LAT.

Proj. Res:

Request For Action **Number: 11**

Project	Gamma-ray Large Area Space Telescope (GLAST)
System/Instrument:	Large Area Telescope (LAT)
Review:	Critical Design Review (CDR)
Date:	May 12-16, 2003

Originator: Jim Ryan
Larry Mignosa
Phone: 301-286-4975 **Organization:** GSFC/543

Category: Mechanical

Title: Use of Contingency Mass in LAT Design and Analysis

Action : Mass properties for LAT design and analysis should include contingency mass.

Supporting Rationale: Analysis and design of the LAT instrument should be done for the maximum or allocated mass of the instrument and should include harness mass as well as the maximum subsystem mass allocations.

Proj. Res:

Request For Action **Number: 12**

Project	Gamma-ray Large Area Space Telescope (GLAST)
System/Instrument:	Large Area Telescope (LAT)
Review:	Critical Design Review (CDR)
Date:	May 12-16, 2003

Originator: Jim Ryan **Phone:** 301-286-4975 **Organization:** GSFC/543

Category: Mechanical

Title: Provide Comprehensive Stress Analysis Report

Action Requested: Provide comprehensive stress analysis report for LAT primary structure and interfaces.

Supporting Rationale: Limited detail analyses was presented at the CDR.

Proj. Res:

Request For Action **Number: 13**

Project	Gamma-ray Large Area Space Telescope (GLAST)
System/Instrument:	Large Area Telescope (LAT)
Review:	Critical Design Review (CDR)
Date:	May 12-16, 2003

Originator: Jim Ryan	**Phone:** 301-286-4975	**Organization:** GSFC/543
Sharon Seipel	301-286-8147	GSFC
E. Shippey	301-286-4901	GSFC

Category: MGSE

Title: MGSE Detailed Dimension Study

Action Requested: a) Perform detailed dimension study. Crane hook height appears inadequate for installation of ACD:
I&T. pg 30 – crane hook height = 134 in.
I&T, pg 31 – ACD needs 124 in.
10 in.
Lift Fixture Box Beam, pg 32 - -6 in.
Difference (including ACD Clearance and Crane Fittings = 4 in.
b) Provide information on the clean room entrances and clearances that will exist when equipment (including GSE) is brought in and out.

Supporting Rationale: a) Risk of damage to ACD hardware during installation, or inadequate facilities to perform operation. Minimum clearance between the bottom of the ACD and top of tracker recommended to be at least 6 in.
b) Not enough detail presented.

Proj. Res:

Request For Action **Number: 14**

Project	Gamma-ray Large Area Space Telescope (GLAST)
System/Instrument:	Large Area Telescope (LAT)
Review:	Critical Design Review (CDR)
Date:	May 12-16, 2003

Originator: Jim Ryan	**Phone:** 301-286-4975	**Organization:** GSFC/543
Sharon Seipel	301-286-8147	GSFC

Category: MGSE

Title: Lack of ACD and Radiator MGSE Information

Action Requested: a) No concept or treatment of radiator installation was presented. Design and analysis needs to be completed to ensure radiator handling loads are properly addressed and all interface requirements are captured in the S/C-LAT ICD.
b) No presentation of ACD installation MGSE.

Supporting Rationale: a) Necessary for CDR. Analysis of handling load cases must be completed prior to radiator fabrication.
b) Necessary for CDR.

Proj. Res:

Request For Action **Number: 15**

Project	Gamma-ray Large Area Space Telescope (GLAST)
System/Instrument:	Large Area Telescope (LAT)
Review:	Critical Design Review (CDR)
Date:	May 12-16, 2003

Originator: Jim Ryan
Sharon Seipel **Phone:** 301-286-4975
301-286-8147 **Organization:** GSFC/543
GSFC

Category: Mechanical

Title: Mechanical Qualification Testing with Spacecraft Flexures

Action Requested: LAT should perform mechanical qualification of the instrument using the spacecraft flexure set being provided by Spectrum Astro.

Supporting Rationale: Using the spacecraft flexures will provide the correct load path for qualification testing of the LAT structural design. If they are not used, extensive pre-test analyses will be required to show that proper load levels (limit X1.25) are being developed with the test GSE and in the proper distribution.

Proj. Res:

Request For Action **Number: 16**

Project	Gamma-ray Large Area Space Telescope (GLAST)
System/Instrument:	Large Area Telescope (LAT)
Review:	Critical Design Review (CDR)
Date:	May 12-16, 2003

Originator: Jim Ryan
Sharon Seipel **Phone:** 301-286-4975
301-286-8147 **Organization:** GSFC/543
GSFC

Category: Mechanical

Title: Assessment of the MECO High Frequency Transient

Action Requested: The low-level sine sweep test out to 150 Hz for assessment of the MECO high frequency transient event was not presented for any of the LAT subsystems. This testing is required by the MAR, and would be best performed at both the subsystem and LAT levels. Finding issues during subsystem testing reduces risk.

Rationale: At a minimum the LAT level test must be performed.

Proj. Res:

Request For Action **Number: 17**

Project	Gamma-ray Large Area Space Telescope (GLAST)
System/Instrument:	Large Area Telescope (LAT)
Review:	Critical Design Review (CDR)
Date:	May 12-16, 2003

Originator: Tom McCarthy
Jim Ryan **Phone:** 301-286-4710
301-286-6003 **Organization:** GSFC/545
GSFC/543

Category: Mechanical

Title: Conduct Mechanical/Thermal Peer Review

Action Requested: Convene a Mechanical/Thermal peer review to examine the results of the engineering analyses and test programs for the following: a) Calorimeter-Grid Structural Joint, b) Tracker, c) X-LAT Panel Interface and Electronics, and d) LAT STOP and out-of-plane motion/distortion analyses

Rationale: These engineering test programs represent liens against the CDR presented design.

Proj. Res:

Request For Action **Number: 18**

Project	Gamma-ray Large Area Space Telescope (GLAST)
System/Instrument:	Large Area Telescope (LAT)
Review:	Critical Design Review (CDR)
Date:	May 12-16, 2003

Originator: Tom McCarthy **Phone:** 301-286-4710 **Organization:** GSFC/545

Category: Systems Engineering

Title: Improving Temperature Margin on Tracker and Calorimeter

Action Requested: Provide a list of actions that systems engineering will take to regain temperature margin on the Tracker (and Calorimeter) as well as any other component that is less than 5 deg. C from its predicted operating limit.

Supporting Rationale: IRD thermal design shows (by analysis) the Tracker temperature at its operating limits and offers no margin to absorb real hardware test results.

Proj. Res:

Request For Action **Number: 19**

Project	Gamma-ray Large Area Space Telescope (GLAST)
System/Instrument:	Large Area Telescope (LAT)
Review:	Critical Design Review (CDR)
Date:	May 12-16, 2003

Originator: Tom McCarthy **Phone:** 301-286-4710 **Organization:** GSFC/545

Category: Systems Engineering

Title: Thermal Design Acceptance Criteria Under Failure Condition

Action Requested: What is the requirement that is used to measure the adequacy of the thermal design in a "failure scenario" (ie. failed heat pipes)? Is it operating limits or acceptance limits?

Supporting Rationale: Current thermal design does not support Tracker hot spot less than or equal to 30 degrees C under failed heat pipe condition (Tracker @ 33 degrees C).

Proj. Res:

Request For Action **Number: 20**

Project	Gamma-ray Large Area Space Telescope (GLAST)
System/Instrument:	Large Area Telescope (LAT)
Review:	Critical Design Review (CDR)
Date:	May 12-16, 2003

Originator: Tom McCarthy **Phone:** 301-286-4710 **Organization:** GSFC/545

Category: Thermal

Title: Thermal Design Failure Mitigation Scenario

Action Requested: a) Investigate the addition of over-temperature thermostats to VCHP reservoir to preclude over-temperature condition identified in failure analysis summary on chart 40. b) Evaluate the use of dual line CCHP (versus baselined single line CCHP) to the X–LAT heat pipe panel at GASU location.

Supporting Rationale: a) Over-temperature of the VCHP reservoir could result in catastrophic loss of radiator.
b) Design needs to be one heat pipe failure tolerant. This design does not meet this requirement.

Proj. Res:

Request For Action **Number: Suggestion**

Project	Gamma-ray Large Area Space Telescope (GLAST)
System/Instrument:	Large Area Telescope (LAT)
Review:	Critical Design Review (CDR)
Date:	May 12-16, 2003

Originator: Tom McCarthy **Phone:** 301-286-4710 **Organization:** GSFC/545

Category: Thermal

Title: Improving Radiator Efficiency

Action Requested: Consider adding horizontal CCHPs to radiator to increase radiator efficiency, and thereby gain some thermal design margin on Tracker temperature.

Supporting Rationale: a) Changes to radiator configuration for PDR have decreased radiator efficiency. In addition, instrument dissipation has increased by 12 W.
b) Note that in test, the horizontal heat pipe won't operate and this efficiency will only be realized on orbit.

Proj. Res:

Request For Action **Number: 21**

Project	Gamma-ray Large Area Space Telescope (GLAST)
System/Instrument:	Large Area Telescope (LAT)
Review:	Critical Design Review (CDR)
Date:	May 12-16, 2003

Originator: Tom McCarthy **Phone:** 301-286-4710 **Organization:** GSFC/545

Category: Mechanical

Title: Radiator Panel MGSE and Wet Joint Process

Action Requested: a) Provide design of MGSE required for installation and removal of radiator panels.
b) Provide process/method planned for making a "wet joint" at radiator heat pipe interface to grid in the vertical orientation.

Rationale: This information was not provided at the CDR.

Proj. Res:

Request For Action **Number: 22**

Project	Gamma-ray Large Area Space Telescope (GLAST)
System/Instrument:	Large Area Telescope (LAT)
Review:	Critical Design Review (CDR)
Date:	May 12-16, 2003

Originator: Tom McCarthy **Phone:** 301-286-4710 **Organization:** GSFC/545

Category: Thermal

Title: Box Level Thermal Design Analysis

Action Requested: a) Provide temperature summary for the TEM, TEM PS and SIU similar to the worksheets for GASU and PDU thermal analysis. b) What independent review is provided for the box level thermal design analyses?

Supporting Rationale: a) Information missing from analysis package. b) Lead thermal systems engineer is not responsible for box level design and analysis, so who provides review?

Proj. Res:

Request For Action **Number: 23**

Project	Gamma-ray Large Area Space Telescope (GLAST)
System/Instrument:	Large Area Telescope (LAT)
Review:	Critical Design Review (CDR)
Date:	May 12-16, 2003

Originator: Tom McCarthy, Sharon Seipel **Phone:** 301-286-4710, 301-286-8147 **Organization:** GSFC/545, GSFC

Category: Thermal

Title: Observatory Level Thermal Testing Requirements

Action Requested: Section 8C, pg 43: Capture thermal testing requirements which apply at observatory level thermal testing in the ICD with Spectrum Astro (ramp rate, etc..). The same attention should be given to capture all LAT unique requirements for all observatory level tests.

Rationale: Necessary to capture all observatory test requirements to keep instrument safe in the Spacecraft-:LAT ICDs.

Proj. Res:

Request For Action **Number: 24**

Project	Gamma-ray Large Area Space Telescope (GLAST)
System/Instrument:	Large Area Telescope (LAT)
Review:	Critical Design Review (CDR)
Date:	May 12-16, 2003

Originator: Steve Scott **Phone:** 301-286-2529 **Organization:** GSFC/500

Category: Mechanical

Title: Assessment of Structural-Thermal Distortions on LAT

Action Requested: Explain how LAT will assess the impact of structural-thermal distortions on LAT pointing knowledge error in support of observatory-level STOP analysis. Estimate the impact if the distortions turn out to be an order of magnitude (10-20 times) larger than specified. Provide the analytical results that bound the LAT's out of plane motion with respect to the LAT Interface Plane (LIP). Provide the necessary models (thermal, mechanical, optical) and support to Spectrum Astro to complete the observatory-level STOP analysis.

Supporting Rationale: The ability of the LAT CDR and Spacecraft PDR design to meet the mission pointing knowledge cannot be determined without a piecewise and/or STOP analysis. The LAT-SC interface is a questionable area. There was a detailed discussion of the planned STOP analysis at the spacecraft PDR but none at the LAT CDR. Information is needed to complete the observatory analysis. This is carried as a top spacecraft risk. A full STOP analysis could take as long as 6 months and a piecewise analysis may be faster. The LAT development proceeds at risk the longer it takes to determine whether LAT's CDR design and spacecraft interface is enough to meet pointing knowledge requirements.

Proj. Res:

Request For Action **Number: 25**

Project	Gamma-ray Large Area Space Telescope (GLAST)
System/Instrument:	Large Area Telescope (LAT)
Review:	Critical Design Review (CDR)
Date:	May 12-16, 2003

Originator: Steve Scott **Phone:** 301-286-2529 **Organization:** GSFC/500

Category: Science

Title: Analysis and Simulation for LAT-Spacecraft Alignment

Action Requested: Present the analysis/simulation leading to LAT-Spacecraft alignment to better than 15 arc-sec (chart 61, Science Requirements*) and explain the apparent disconnect with the 4 arc-sec requirement quoted on chart 52*. Explain how source location to 10 arc-sec is done in a month (chart 60*) when the alignment may not be known to better than 15 arc-sec. Provide the calibration plan that explains this correlation. *backup charts in handouts.

Rationale: There is an apparent disconnect between requirements and performance estimates.

Proj. Res:

Request For Action **Number: 26**

Project	Gamma-ray Large Area Space Telescope (GLAST)
System/Instrument:	Large Area Telescope (LAT)
Review:	Critical Design Review (CDR)
Date:	May 12-16, 2003

Originator: Steve Scott **Phone:** 301-286-2529 **Organization:** GSFC/500

Category: Science

Title: LAT and GBM Performance Comparison

Action : For sources within the LAT FOV, compare LAT and GBM performance in detecting bursts.

Supporting Rationale: LAT needs GBM to provide alerts for bursts outside the LAT FOV. It is not clear if LAT needs GBM alerts in all cases.

Proj. Res:

Request For Action **Number: 27**

Project	Gamma-ray Large Area Space Telescope (GLAST)
System/Instrument:	Large Area Telescope (LAT)
Review:	Critical Design Review (CDR)
Date:	May 12-16, 2003

Originator: Steve Scott **Phone:** 301-286-2529 **Organization:** GSFC/500

Category: Schedule

Title: Schedule for Completion of Engineering Drawings

Action Requested: Present a plan and schedule for completion of engineering (subsystem) drawings that is sensitive to need dates and the critical path. Describe the process used to check drawings to determine readiness for release.

Supporting Rationale: Released drawing status is behind schedule for CDR. It is not clear if need dates and LAT development critical path are dictating the priorities or whether this is being left to chance and whatever is easiest to complete first.

Proj. Res:

Request For Action **Number: 28**

Project	Gamma-ray Large Area Space Telescope (GLAST)
System/Instrument:	Large Area Telescope (LAT)
Review:	Critical Design Review (CDR)
Date:	May 12-16, 2003

Originator: Steve Scott **Phone:** 301-286-2529 **Organization:** GSFC/500

Category: C&DH

Title: Process for Performing Worse Case Circuit Analysis

Action Requested: Describe the process for performing worse case circuit analyses for electronic circuits to show that the electronics can perform over its full temperature range over the life of the mission. Provide the results of these analyses, if you have performed these analyses. If you have not performed WCCA's, then perform them. I suggest using NASA JPL preferred reliability practice PD-ED-1212 as a guideline.

Rationale: This has not been described, although WCCA's may have been performed.

Proj. Res:

Request For Action **Number: 29**

Project	Gamma-ray Large Area Space Telescope (GLAST)
System/Instrument:	Large Area Telescope (LAT)
Review:	Critical Design Review (CDR)
Date:	May 12-16, 2003

Originator: Steve Scott **Phone:** 301-286-2529 **Organization:** GSFC/500
Joe Bolek 301-286-1390 GSFC/593

Category: C&DH

Title: GLAST LAT Fault Management

Action Requested: Describe fault management for GLAST LAT. Describe fault management for GLAST LAT by the GLAST spacecraft. The description of fault management should include hardware and software (and operational techniques). Describe where requirements are defined and how they are verified.

Rationale: Fault management for the GLAST LAT has not been adequately (ie., thoroughly) addressed.

Proj. Res:

Request For Action **Number: 30**

Project	Gamma-ray Large Area Space Telescope (GLAST)
System/Instrument:	Large Area Telescope (LAT)
Review:	Critical Design Review (CDR)
Date:	May 12-16, 2003

Originator: Steve Scott **Phone:** 301-286-2529 **Organization:** GSFC/500
Don Kniffen

Category: Testing

Title: Beam Test Plan

Action Requested: The test plan shows no tagged photons between 17.6 MeV and 100 MeV. The gap between these two energies represents an energy range where the instrument sensitivity varies most rapidly with energy. In principle, bremsstrahlung photons can be produced in this gap. A couple of energy points should be inserted in the beam test plan.

Supporting Rationale: The energy range below 100 MeV is very important astrophysically. The instrument response in this region needs to be confirmed.

Proj. Res:

Request For Action **Number: 31**

Project	Gamma-ray Large Area Space Telescope (GLAST)
System/Instrument:	Large Area Telescope (LAT)
Review:	Critical Design Review (CDR)
Date:	May 12-16, 2003

Originator: Steve Scott, C. Lorentson **Phone:** 301-286-2529, 301-286-4904 **Organization:** GSFC/500, GSFC

Category: Contamination

Title: Impact of the Conductive Carbon Particles

Action Requested: Review the impact of the conductive carbon particles that are being generated within the instrument. Evaluate methods to reduce/eliminate the production of these contaminants. Demonstrate the methods used to ensure/verify that these particles will not cause a short or other failure.

Supporting Rationale: The 750 B contamination level was developed for general contamination materials. The high number/percentage of conductive particles greatly increases the likelihood of a short. This is a workmanship concern and could impact systems other than this instrument as well.

Proj. Res:

Request For Action **Number: 32**

Project	Gamma-ray Large Area Space Telescope (GLAST)
System/Instrument:	Large Area Telescope (LAT)
Review:	Critical Design Review (CDR)
Date:	May 12-16, 2003

Originator: Phil Sabelhaus **Phone:** 301-286-5712 **Organization:** GSFC/

Category: Testing

Title: Testing of Calorimeter Engineering Module with Latest ASIC's

Action Requested: Consider testing the Calorimeter Engineering Module with the latest version of the GCFE ASIC's (GCFE9) in order to understand ASIC performance at the system level.

Supporting Rationale: Important to understand if a new batch of ASIC's are needed as soon as possible. Don't want to find out that new ASIC's are needed after starting to build flight unit Calorimeter units.

Proj. Res:

Request For Action **Number: 33**

Project	Gamma-ray Large Area Space Telescope (GLAST)
System/Instrument:	Large Area Telescope (LAT)
Review:	Critical Design Review (CDR)
Date:	May 12-16, 2003

Originator: Jim Rose **Phone:** 818-354-4491 **Organization:** HQ/IRT

Category: Systems Engineering

Title: Possible Temperature Rise Due to Rise in Detector Event Rate

Action Requested: Describe the design/operations process/procedure that will prevent excessive temperature rise due to extraordinary event rate of detections (exciting science) sustained for multiple hours. a) What causes the instrument to reach its maximum power consumption? b) What limits the duration of this maximum power state? c) Is it possible to exceed temperatures predicted on a 750 W for 10 minutes specification basis?

Supporting Rationale: Don't know about the universe, but it seems like the hot thermal case is marginal, and the instrument could exceed the 10 minute limit on maximum power consumption.

Proj. Res:

Request For Action **Number: 34**

Project	Gamma-ray Large Area Space Telescope (GLAST)
System/Instrument:	Large Area Telescope (LAT)
Review:	Critical Design Review (CDR)
Date:	May 12-16, 2003

Originator: H. Spieler **Phone:** 510-486-6643 **Organization:** LBNL

Category: Install Calorimeter Test Module with Flight ICs Before I&T

Title:

Action Requested: Equip Calorimeter Test Module with flight ICs before passing it on to I&T.

Supporting Rationale: System test with flight ICs should commence as soon as practical

Proj. Res:

Request For Action **Number: 35**

Project	Gamma-ray Large Area Space Telescope (GLAST)
System/Instrument:	Large Area Telescope (LAT)
Review:	Critical Design Review (CDR)
Date:	May 12-16, 2003

Originator: Ron Ray **Phone:** 630-840-8090 **Organization:** Fermilab

Category: Testing

Title: Accelerated Performance Life Testing of PIN Diode Elastomer

Action Requested: Perform accelerated performance life testing of PIN diode elastomer and set aside a few devices for long term monitoring.

Supporting Rationale: The elastomer being used for the PIN diodes has no flight history.

Proj. Res:

Request For Action **Number: 36**

Project	Gamma-ray Large Area Space Telescope (GLAST)
System/Instrument:	Large Area Telescope (LAT)
Review:	Critical Design Review (CDR)
Date:	May 12-16, 2003

Originator: Ron Zellar **Phone:** 301-286-5842 **Organization:** GSFC/582

Category: Software

Title: Addition of Test Engineers to Software Team

Action Requested: Investigate options for the addition of engineering resources tasked with the responsibility of developing test procedures, maintaining the Software Test Plan, and defining a test procedure development schedule.

Supporting Rationale: The development calls for an unrealistically high code production rate of approximately 25-30 verified lines of code per day per person. This rate is about 3 times higher than the industry standard. Clearly additional staffing will be required to allow the successful production of software and support of I&T.

Proj. Res:

Request For Action **Number: 37**

Project	Gamma-ray Large Area Space Telescope (GLAST)
System/Instrument:	Large Area Telescope (LAT)
Review:	Critical Design Review (CDR)
Date:	May 12-16, 2003

Originator: Tom McCarthy **Phone:** 301-286-4710 **Organization:** GSFC/545

Category: Thermal

Title: Investigate XLAT/Electronics Interface Design Option

Action Requested: Provide a design option (revisit PDR design) for the XLAT/electronics interface that implements a hard mounted, bolted, connection versus the proposed flexible joint for this critical thermal interface.

Supporting Rationale: The current development plan for this flexible thermal joint may not provide conclusive results that will mitigate the risk of implementing this type of joint at the only interface that provides the heat transfer path to the LAT radiation system for the LAT electronics.

Proj. Res: